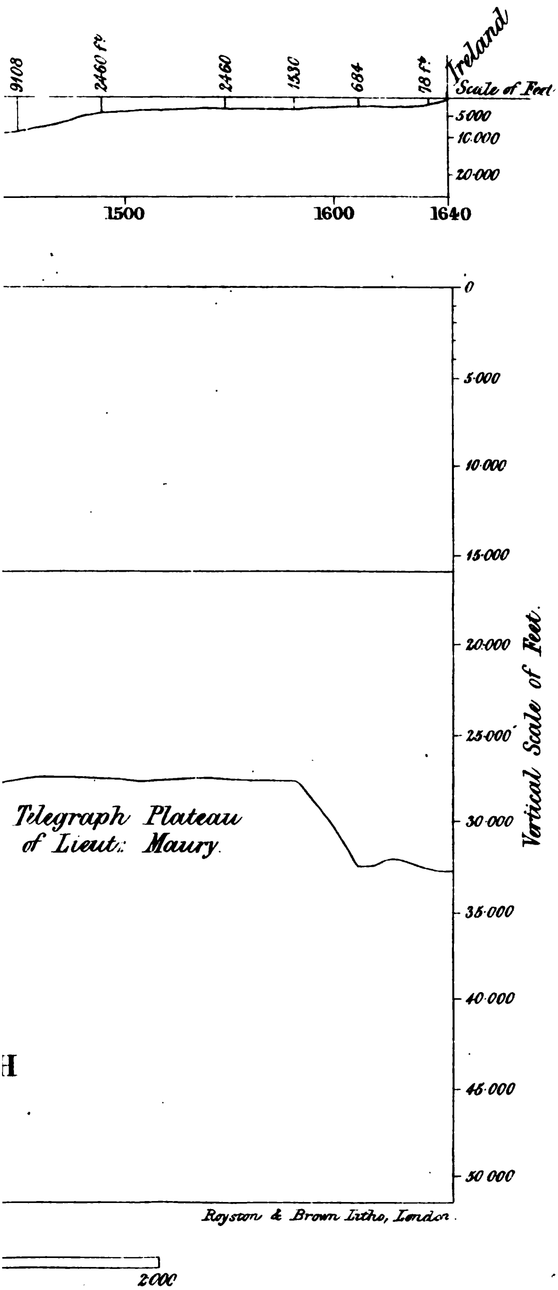

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THE ATLANTIC TELEGRAPH.

A HISTORY OF PRELIMINARY

EXPERIMENTAL PROCEEDINGS,

AND A

DESCRIPTIVE ACCOUNT

OF THE

PRESENT STATE & PROSPECTS OF THE UNDERTAKING.

PUBLISHED BY ORDER OF THE DIRECTORS OF THE COMPANY.

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THE ATLANTIC TELEGRAPH COMPANY,

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THE ATLANTIC TELEGRAPH.

The establishment of an Electric Telegraph between the Old and the New Continents, is obviously an enterprise which has no precedent in the annals of mechanical engineering; the object proposed being nothing less than the commercial annihilation of distance in respect to one of the great Gulfs which have been placed between the East and the West;—the opposite halves of the habitable world.

Most people are aware that this surprising telegraphic connection is in process of being realized. The eyes of the entire civilized community are, indeed, directed with ever-increasing interest and expectation at the present time to the proceedings of the Company which has undertaken the labour; and two of the greatest Governments of the earth have been induced to accord their cordial and substantial support. Under this manifestation of sympathy and approval, execution in the mighty task has followed so closely upon plan, that in all probability the origin and completion of the work will be *comprised within the compass of a single year.* Nevertheless, every detail in the design has had to be deliberated upon and matured before a single step in execution could be set; an advantage which has only been secured by stretching the mental energies, and tasking the bodily strength of all who have been concerned in the work, to the utmost. The Directors of the Company feel that for various reasons it is due to the sympathizing public at large, as well as to the co-operating shareholders and the executive officers, now to place before the world a full statement of their past proceedings, and of the ground upon which they confidently look forward to a speedy consummation of their task.

Some years have passed since the notion was first formed that it might be possible so to insulate a conducting wire, and lodge it in the depths of the sea, that electrical signals might be made through considerable distances in the water. Even as long back as the year 1842 an attempt was actually made to transmit, for telegraphic purposes, an electrical current through an insulated wire laid in water. Professor

Morse of New York, in the month of October in that year, stretched a submarine conducting cable from Castle Garden to Governor's Island, in the harbour, and was able to demonstrate to a Committee of the American Institute the possibility of effecting electric communication through the sea, although the transmitting cable was destroyed by the anchor of a vessel almost as soon as telegraphic operations had commenced. The Professor received the award of the gold medal of the Institute upon this occasion, as an acknowledgment of his success. Under the date of August 10th, 1843, Professor Morse wrote, in consequence of further investigations, to the Secretary of the United States Treasury, "The practical inference from the law just elucidated is that a telegraphic communication on my plan may with certainty be established *across the Atlantic!* Startling as this statement may *now* seem, the time will come when the project will be realized." In 1851 a submarine electrical connection was established between France and England. This first step having been set, it was impossible that so good an example should long remain unfollowed. The importance of rapid and certain communication between distant parts of civilized realms, is so obvious to every person of any measure of intelligence, that means for extending submarine connection with the island centre of commercial enterprize, were sure to be forthcoming to any required extent, when once the practicability of the affair had been demonstrated by experimentalists and men of science. There are, accordingly, now six several submarine telegraphic cables running from England to adjacent shores. All this, however, is but the preparation for the end prophetically announced by Professor Morse, and naturally marked out as the ultimate aim of the art of "signalling or writing afar." The Anglo-Saxon race, which is in the van of all social progress, dwells on *both sides* of the Atlantic. Two thousand miles of water stretch between Englishmen, and their own kith and kin in the West. If it be an important thing that eleven hours of time shall be saved when a message has to be sent from London to Paris, or that nine hours shall be saved when an intimation has to be transmitted from Liverpool to Dublin, how much more important it is that *fourteen days* should be economized when information has to be forwarded from Liverpool or London to the United States, and to the British North American Colonies, or to be sought from them. Upon Lieut. Maury's being asked whether he conceived that the establishment of the Atlantic Telegraph along the proposed line would give Great Britain any advantage over the United States "in a military point of view," he answered, that in case of the breaking out of war, it was certain no high-minded people would ever dream of employing a cable con-

secrated to the service of commerce, the advancement of science, and the benefit and improvement of the whole human family, as a mere military engine. Professor Morse, the day after he disembarked at Gravesend from the Niagara, upon that vessel's recent arrival in England upon her interesting mission of co-operation and help, while speaking of the prospects and promises of the cable, went further into the real pith of the matter than Lieutenant Maury did in his official reply. The Professor stated as one great reason for his own personal anxiety to see the cable in active operation through the depth of the sea, a firm conviction that then the chances of conflict and misunderstanding between Englishmen and Americans must be diminished in an incalculable degree. Lieutenant Maury *argued* that no British Government either would or could use a Submarine Atlantic Telegraph for hostile purpose. Professor Morse *feels* that when the Atlantic Cable is at the bottom of the ocean, there can be no hostile purpose for which its strands could be pressed into service; and that when New York is a suburb of London, and Washington the western half of Westminster, an American war will be about as likely a thing as Camberwell organizing an attack upon Camden Town, or Peckham making a raid upon Pimlico. All wars arise in ignorance and misunderstanding of the real objects and interests of the races by which they are waged. To increase the facilities for the interchange of ideas, for the opening out of commercial relations, and for the development of intelligence, must be to diminish the need of appeals from reason to force. The small cable laid quietly at the bottom of the Atlantic, at a cost of £350,000, will do more for the maintenance of international peace, and for the furtherance of national prosperity, than an expenditure of ten millions a year, on each side of the Atlantic, in the construction and commissioning of such armed Leviathans as will carry and pioneer the electrical rope to its resting-place. The Shareholders of the Atlantic Telegraph Company will not be unwilling to receive Professor Morse's opinion and assurance upon this point, as the first instalment of their interest.

The earliest real step towards the undertaking, which is now auspiciously so far advanced, was taken three years ago. In the month of April, 1854, the Colonial Government of Newfoundland passed an act, incorporating a Company for the Establishment of Telegraphic Communication between the Old World and the New. Shortly afterwards, the same Legislature expressed its interest in the enterprize in a very substantial way, by grants of land and subsidy, and by conferring the exclusive right to land a telegraphic line upon the coast under its jurisdiction, extending the entire length

of Newfoundland and Labrador. The Company having become the recipient of these privileges, next obtained a charter of similar tendency from the Government of Prince Edward's Island, and from the State of Maine, and also secured authority for certain subsidiary operations in Canada, besides getting a ratification and confirmation of its rights from her Majesty's Ministers at home.

The Incorporated Company, henceforth known under the denomination of "The New York, Newfoundland, and London Telegraph Company," having appointed Professor Morse their electrician, next proceeded to connect St. John's, Newfoundland, with the lines already in operation in the British North American provinces, and in the United States, by immersing thirteen miles of cable across the Straits of Northumberland, and eighty-five miles in the waters of the St. Lawrence. England and the continent had already been connected with Ireland, irrespective of any design to extend the telegraphic communication towards the West. There therefore remained only a single gap to be filled in—the basin of the Atlantic itself.

The Newfoundland Company having completed these preliminary steps, with a singular exertion of judgment and good sense, placed itself in communication with the most experienced authorities in electrical and mechanical affairs on this side the ocean, and made strenuous efforts to combine all the skill and intelligence it could command in advancing towards the solution of the problem upon its hands. In the investigations which were now entered upon, Mr. Wildman Whitehouse, at present the electrician of the Company, and Mr. Charles Bright, its engineer, and the engineer of the Magnetic Telegraph Company, took a prominent part. As early as 1854, these two gentlemen were occupied upon a series of experiments, to determine the influence of induction and disguised electricity in retarding the transmission of currents along submarine wires, and since then they have been conjointly and separately prosecuting the important investigation. Before alluding to these experiments, or their results, it will be necessary to offer a few words of familiar explanation regarding the principle which is involved.

In the ordinary arrangement of the wires of the electric telegraph, where these are stretched between posts, and insulated simply by glass or earthenware holders and the investing air, the current of electricity runs along as a simple stream, and with a velocity that is almost inappreciable for any distance numbered by a few hundreds of miles. When, however, the wires are enclosed in a compact sheath of insulating substance, such as gutta percha, and are placed in a moist medium, or in a metallic envelope, the case is materially changed.

The influence of induction then comes into play as a retarding power to a very sensible extent. So soon as the insulated central wire is electrically excited, that electrical excitement operates upon the near-at-hand layer of moisture or of metal, and calls up in it an electrical force of an opposite kind. These two different kinds of electricity then pull at each other, to use a homely phrase, through the intervening layer of impenetrable insulator, and each "*disguises*" an equivalent portion of the other—that is, holds it fast locked in its own attraction, and so renders it, for the time, valueless as an agent of extraneous power. The inner electricity keeps the outer induced force stationary upon the external surface of the insulating sheath. The outer induced electricity keeps a certain portion of the inner, excited influence, on the interior surface of the insulating sheath *as a charge*, and so prevents it from moving freely onward on its journey as it otherwise would. It is precisely the same thing as the effect which is produced when the ordinary Leyden jar of the experimentalist is charged by a frictional machine. The excitement produced in the inner surface of the glass jar, inductively charges the outer surface, left in metallic communication with the earth, with an opposite kind of force. The external electricity then holds the internal imprisoned and intensified, as it were, by its strong efforts to get to its attractive neighbour through the glass. The submarine telegraph cable is indeed virtually a lengthened-out Leyden jar, and transmits signals while being charged and discharged, instead of merely by allowing a stream of the electrical influence to flow dynamically and evenly along it. It is a *bottle* for the electricity, rather than a simple channel or *pipe* open freely at both ends, and every time that it is used it has to be first filled, and then emptied. When an extent of many miles is concerned, it gets too to be a very capacious bottle in virtue of its length, however narrow its transverse diameter may be. This peculiar character of a submerged or metal-sheathed insulated wire was not suspected at the first, for the simple reason that in the usual practice of artificially produced electricity, the voltaic current does not communicate a statically intense charge of electricity to a Leyden jar. In the arrangement of the telegraph wire, an important modification of the ordinary conditions is introduced. In this case, the voltaic current is able to charge statically the internal insulated conductor, in consequence of some as yet unascertained peculiarity of its relations, probably connected with the comparatively enormous extent of the surface that is concerned. The attention of electricians was first drawn to the peculiarity by the extraordinary and altogether unexpected retardation which the electrical current was found to suffer when it

had to pass through subterranean or submarine channels in the course of its journey. In 1851, six gutta percha covered wires were laid by the Magnetic Telegraph Company from Liverpool to Wigan and Manchester, a distance of forty-one miles. In these the power of induction to retard the movement of the current, and also to cause a secondary or return current to pass from the wire to the earth, on withdrawing the cause of primary excitement, was distinctly observed. It was also noted that on connecting the six wires into one continuous circuit, the phenomena were manifested in a much greater degree. In the early experiments made for the determination of the speed with which the subtle influence travelled along metallic wires, hundreds of thousands of miles appeared to be traversed in a second of time. But when a similar examination was entered upon with telegraphic lines running between London, Manchester, and Glasgow, and laid underground, and between London and Paris, and London and Brussels, partly underground, and partly submarine, it seemed that scarcely thousands of miles were passed in the same period; indeed, the statement was made in a paper read by Mr. Edward Bright, at the meeting of the British Association in 1854, that the velocity of currents in ordinary use for telegraphic purposes in subterranean conductors did not exceed one thousand miles per second; this gentleman also inferred from experiments carried on in a circuit of 480 miles of underground wire, that the speed with which an electrical impulse was transmitted varied with the energy or intensity of the current employed, and the nature and conditions of the conductor used, and hence that the rate of transmission might be greatly increased at will by adopting currents of a different character to those which had been habitually trusted to. Professor Faraday had at once attributed these experimental discrepancies to their true cause; and Mr. Whitehouse exhibits a very beautiful and convincing experimental proof that it is as Leyden jars, and by retention of charge, that submarine cables act. He takes first fifteen miles of insulated wire with a conducting layer external to its insulating investment, and turns up its further end into the air, and he then does the same thing with a 200 miles length of the same wire. He next communicates as full a charge to each of these lengths as they have the capacity to retain. Then he discharges each, allowing the discharge to flow through a fine wire coiled round a bar of soft iron, so that the bar may be rendered a magnet *pro tempore* during the actual current of the electricity. Upon measuring the force of each discharge current, estimating it by the number of grains the temporary magnet is able to lift, he finds that where the fifteen-mile length of the wire is concerned, the weight lifted amounts to 1075 grains, and

that where the two-hundred-mile length is concerned, the weight lifted amounts to 2300 grains. A current which lifted 18,000 grains by simply running through the apparatus thus arranged, upon being sent into a coated insulated wire 498 miles long, lifted 60,000 grains when allowed to flow back as discharge, and even 96,000 grains if the discharge passed from both ends of the wire at once, and round the same temporary magnet. The significance of this result, reduced to plain terms, is simply this—the wires act as reservoirs, and not as mere channels, and accordingly the larger reservoir receives and holds a larger quantity of the influence than the smaller one, and this larger quantity naturally produces the most powerful effects when it is allowed to escape from its imprisonment. If the wires were acting as common conductors, the longer wire would produce the weaker effect on account of the electrical influence being attenuated through its extent. As they are operating as Leyden jars, or reservoirs, the longer wire is the most capacious receptacle, and produces the most energetic result, as its contents are poured out. It is now a familiar fact, that sensitive magnetic needles, placed by the side of a long and completely insulated wire when it is charged, give clear indication of the first "rush" of the influence into the wire, of the retention of the charge for several minutes after the charging contact has been broken, and of the final "rush out," or discharge of the influence in the opposite direction, when the wire is connected with the earth by its nearer end.

When the fact had been satisfactorily made out that the insulated marine wire must act as a Leyden jar, and be affected by charge and discharge, it became a matter of the highest practical importance to determine whether there was any peculiarity in this mode of operation which might be expected to interfere with the final success of telegraphy, in its application to long distances of sea circuits. A length of 166 miles of cable chancing to be in process of manufacture at Greenwich, the opportunity was seized to carry practical research into the matter. This cable contained three very perfectly insulated wires, arranged side by side in its core of gutta percha, in such a manner that they could very easily be connected together by their ends, so as to make an available length of wire for experiment of 498 miles.

The first thing done with this arrangement was the experimenter's satisfying himself that he might use the results of his experiments as fair expressions of what would take place in an extended wire 498 miles long, notwithstanding the three several wires, which formed successive parts of the line, lying side by side in the narrow dimensions of the gutta percha core. A careful examination was made of the influence

each wire exerted upon its neighbour, in setting up slight charges of an opposite kind of electricity inductively, and it was found that the inductive influence thus exerted was only a ten-thousandth part of that which was transmitted along either of the wires 166 miles long. The results were attained by passing currents in various directions and in various ways along three wires simultaneously, and by estimating the differences of power in each, by their diverse capabilities of magnetising soft iron bars.

Another step taken about this time, the importance of which to the future working of long marine lines can hardly be over-estimated, was the providing of very sensitive receiving instruments, which could be set in action to record signals instantaneously by the influence of the long current. These consist, as now perfected, of an apparatus adapted to call into play small relay-batteries of a voltaic character, always ready to work when their opposite poles are brought into contact; a soft iron bar being arranged in such a way that it completes contact for them whenever it is made into a magnet by the passage of the long current through a coil of fine wire wound round it. The receiving instrument for purposes of experimental research is caused to print a trace upon a ribbon of paper by styles pressed down upon it as it is unwound from a drum by clockwork. The paper is saturated with a chemical solution which presents no colour to the eye until it has been decomposed by the agency of a voltaic stream, but which then offers to observation a deep stain. When the receiving instrument is in operation, one of the poles of its battery is continuous with printing styles of steel pressed down on the top of the paper, and the other with a table of metal resting beneath the paper. The voltaic current thus traverses the still moist paper, immediately between the points of the styles and the table. These receiving instruments have been rendered so perfect in their several parts and contrivances, that they readily record telegraphic signals either upon chemically prepared paper, or upon an ordinary Morse's apparatus, upon being excited to do so merely by a small piece of zinc and a sixpence being placed upon the tongue as the sole voltaic element of the arrangement, the current generated being transmitted through 498 miles of wire and the earth, before being employed in the excitation of the instrument. This at any rate is sufficient to prove that Telegraphy on the other side of the Atlantic will be practicable so soon as an influence can be sent there which shall have as much power as this tongue-generated current at a distance of nearly 500 miles. Currents which produce no perceptible influence upon the most sensitive galvanometer of ordinary construction,

at once print distinct signals at almost any distances, through the instrumentality of these delicate auxiliaries. The structural reason for this exquisite delicacy will be more easily understood if explained in connection with the description of the apparatus designed for Atlantic use.

In the year 1855, the opportunities for experimental investigation were greatly extended by the completion at Greenwich, almost simultaneously, of two cables, the one 82 miles long, and destined for Newfoundland, and the other 150 miles long, and destined for the Mediterranean. The Newfoundland cable consisted of three insulated wires, and the Mediterranean cable of six; so that the collective length of the wires, when all were joined together as in the previous experiments, was 1146 miles. Some interesting experiments were also carried out in the same year upon the system of subterranean and submarine wires, which connect London with Dumfries, Portpatrick, Belfast, and Dublin, and which are under the charge of Mr. Charles Bright. These wires extend altogether to a distance of 660 miles. Long lines of aerial or pole telegraph, stretch from Dublin to Cork, Limerick, Waterford, and Killarney, and thus afford convenient means for actually comparing the efficiency of different kinds of currents, and their suitability for employment in aerial and gutta percha covered wires. The pole lines employed in this comparison were admirably adapted for the purpose by the completeness of their insulation. They are supported by large dome-shaped insulators, and are so thoroughly protected that the wettest weather makes no perceptible difference in their power of transmitting signals from end to end. So slight a force is required to operate upon the indicators of these telegraphic wires, that signals are sent from Dublin to Cork, by means of currents generated in coils primarily by the action of permanent magnets, which are worked with the keepers on their poles.

The experimenters engaged upon these practical investigations, had by this time discovered that they stood greatly in need of some more precise method of estimating the time occupied by the transmission of the electrical influence, than they yet possessed. Mr. Whitehouse consequently was led to trace out the first plan of an instrument which has since become in his hands nearly perfect as a scrutinizing agent, and which not only detects differences, but actually places what it detects on record on the instant, so that they can be examined and compared again and again, and collated in every possible way, with a view to eliminate sources of uncertainty and error, by making use of only the best *means* of a great number of observations.

The basis of this scrutinizing instrument is a ribbon of chemically-prepared paper, (like the one already described) unrolled from a drum by clock-work;—receiving instruments which make local batteries print on the ribbon by short circuits when magnetically directed to do so;—and a seconds pendulum vibrating in such a manner that it sends an electrical current opposite ways along the wire under examination at each beat, or half vibration, a result which is brought about by the following arrangement. The pendulum itself hangs upon a pivot, which is one of the poles of an electrical battery, but is prolonged upwards into a sort of crest, that touches a spring right and left as it sways to and fro. The springs, when at rest, press upon a pillar lying between them, which is the other pole of the battery. The crest of the pendulum lifts the one of these springs which it touches, off the pillar for the time. When it lifts the right spring, it sends a current from the positive pole out through it and the wire, and back through the left spring to the negative pole or pillar. When it touches the left spring, it sends a current out through it and the wire the opposite way, and back through the right spring to the negative pole or pillar. The wire is coiled in different places round bars of soft iron. When the current passes through these coils, the bars become magnets for the time, but the precise nature of their magnetism depends on the direction in which the currents run. When the direction is from the right spring of the pendulum apparatus, the North pole of the magnet is where the South pole of the magnet is found when the direction is from the left spring. But near to each of these temporary magnets, there is placed a true and permanent magnet, mounted on a pivot, so that it can traverse right or left. The reversal of the magnetism in the temporary magnet causes the true magnet to move on its pivot as far as it can, because North poles attract South poles, and the reverse. A pole of the temporary magnet being now North, pulls to itself a South pole of the true magnet, which is, however, sent smartly away so soon as the pole of the temporary magnet becomes a South pole itself. When these traversing magnets lie in one direction, they complete the circuit connection of small local batteries, and cause them to print upon the ribbon of prepared paper. When they lie the opposite way, they open or break the circuit, and stop the printing. The pendulum thus reversing the direction of the current of the long wire at each second makes the local battery print one second and stop one second, and then print again. On the unrolling ribbon of paper there are long dark traces, alternated with clear spaces, each being *one second long;* that is repre-

senting in linear measure that interval of time. But there are two or more receiving instruments (according to circumstances) set to work by the same current, sent on by the vibration of the pendulum. If therefore, a wire or cable 1100 miles long be under examination, and one receiving instrument be placed in relation with the commencement of the wire, and another with its end, then the styles of those instruments ranged side by side on the paper ribbon will print just when the current influences the electro magnet belonging to them. If the current does not arrive at one magnet until some appreciable time after the other, the one style will not begin to print until so long after the other style. The one trace on the paper will *lag back* to a certain extent behind the other. But the distance the paper moves in a second is marked each alternate second by the stained trace printed in by the style. Consequently, the distance to which one mark lags back behind the other, or in other words, *the length of time* the electrical current has taken to run through the wire from one receiving instrument to the other, can be estimated with the utmost precision in fractional parts of the length of the printed representative of a second. It does not at all matter what the speed is with which the paper ribbon is unwound beneath the styles, because the estimate of the amount of retardation is always a relative one, capable of being fixed for each instant by the length of the particular track made by the beat of the pendulum. This relation is at once fixed by taking two simple measures by compasses, upon an accurately engraved scale. When the velocity of transmission in any particular arrangement is to be determined, the apparatus is set to work, and prints a lengthened series of observations; these are afterwards carefully examined, and all that seem to be doubtful, being rejected, the more satisfactory ones are added together, and their mean recorded.

Having thus 1146 miles of telegraphic cable under their hands and this delicate piece of scrutinizing apparatus to work with in making investigations, the first fact to be determined by the experimenters was, could any available signal be transmitted through the 1146 miles of conductor. A seconds pendulum was first arranged to turn on the electrical current to the wire at each beat without attempting the reversal of the current. A trace appeared in a very short time under a style connected with the further end of the cable; there could be no doubt of the ability of the electrical influence to make itself telegraphically manifest through that vast extent at least.

There was, however, this curious anomaly in the result of the experiment. The pendulum made connection with the voltaic battery only for an instant at each beat; but the printed trace on the paper was not interrupted. *It was one long continuous line.* The reason for this

was, that the conducting wire did not discharge itself between beat and beat. The current moved so sluggishly and unwillingly in this protracted and induction-encumbered channel, that one transmission was not able to clear itself off, before the next was pressing upon its heels, and in confusion with it.

This was at once felt to be a very important affair, and one that might probably affect materially the fortunes of lengthened submarine telegraphs. In order that telegraphy under such circumstances may be of practical service, it is necessary not only that the telegraphing influence shall be able to traverse to the end of the wire; but it also is essential that it shall be so nimble in its movements as to afford the opportunity for a fair number of signals to be passed in any given time. Otherwise, the telegraph could never be worked remuneratively at charges that would make it of general use. If every distinct signal required a second for the Atlantic line, the probability is, that the undertaking would not prove to be a commercial success, although the cable might be available for exceptional cases and great emergencies.

Impressed with this consideration, the experimenters proceeded to test the actual speed with which signals might be made to succeed each other in an insulated wire 1146 miles long. First, a simple voltaic current was used, and caused to split itself into two equal halves by inserting a column of water in the circuit, which afforded precisely the same resistance to its movement as the 1146 miles of wire. The current then spontaneously divided itself between the wire and the water. A column of water three-eighths of an inch in diameter and thirty inches long, proved to be as strong an obstacle to the passage of the current, as 1146 miles of gutta-percha-covered copper wire of No. 16 gauge. Next, a series of electro-magnetic induction coils were employed;—that is, secondary currents of considerable intensity were set moving inductively by electro magnets, themselves inductively formed by currents circling round them in coils from powerful voltaic combinations. One of the magnets was caused to send its secondary currents directly to a printing instrument. The other magnets were made to transmit their currents to another instrument of like kind through the 1146 miles of wire. Through the intervention of these arrangements, it was determined that even the comparatively sudden and momentary magneto-electrical current took a second and a half to discharge itself, when it moved through 1146 miles of wire, in consequence of the retarding power of induction in this lengthened medium.

The next step was to test the power of art to furnish a remedy for this inductive obstacle. Such arrangements were made with magneto-electric coils, as enabled the operator to send rapid alter-

nations of *different kinds* of electricity along the wire, under the anticipation that each transmission would then serve to clear away the residue of the antagonistic current which had immediately preceded it. A hint, indeed, was taken from what had already been done with long subterranean circuits. Henley's instrument, in previous use on the magnetic lines of telegraph, transmits alternately reversed currents along the wires, these being generated by the motion of electro-magnetic coils, suspended on an axis before the poles of a permanent magnet. The desired end was attained in the present case, by reversing the course of a voltaic current in an induction coil at each renewed signal. Although the same wire and the same magneto-electric combination were employed which had before demanded a second and a half for the completion of a single discharge, *seven and eight currents now readily recorded themselves distinctly in a second!* The residue of the old current which clung pertinaciously about the wire was rapidly and completely discharged by a stream of electricity of the opposite kind. When positive followed negative, and negative followed positive, in exactly equal proportions, the result was that the electrical equilibrium of the wire was continually restored as fast as it is was disturbed, and so its telegraphic capabilities steadily maintained. It was now obvious that no instrument could be expected to be successful in the working of a long submarine line which did not satisfy this condition of the alternate use of opposite currents of the influence, but that by the adoption of such an instrument, one great and indeed fundamental obstacle to the commercial success of extended submarine lines might be hoped to be destroyed.

Professor Faraday had, some time before the institution of these experiments, shown that successive charges of electrical influence may be travelling along lengthened conducting wires simultaneously, the one following the other, as the successive undulations of the tidal wave chase each other along the channel of the River of the Amazons. It was now ascertained, strange to say, that the *alternate opposite currents* could do the same thing. Alternate positive and negative signals were sent along 900 miles of wire, at the rate of eight signals in each second. and *two signals arrived at the end of the wire after the acts of transmission had been discontinued.* By the use of a wire 1020 miles long, in another experiment, three signals of a single-stroke bell were distinctly heard after the movement of the hand, which originated the currents, had ceased.

The conductor of these experiments had now fully learned the great need there was for some more precise and trustworthy

measure for the *force* of moving currents of electricity than science had yet furnished. The old galvanometer, which consists of a magnetized needle suspended freely in a position where electrical currents may be made to course round it in a coil, proved to be of no value whatever when currents of high degrees of force and limited duration came under examination. The needle then commonly turns somersets, and jerks backwards and forwards in the most hysterical and passionate way, instead of maintaining the steady divergence which alone could be accepted by the eye of science as a satisfactory indication of strength. Mr. Whitehouse accordingly resolved that he would make the surest and most stable of all powers, terrestrial gravity, to take upon itself the work magnetic polarity was too impulsive to perform. He determined that he would *weigh* the force of his electrical currents in an actually literal sense. He accordingly prepared a delicate and sensitive steelyard, as the most convenient form of balance for the purpose he had in view, and he hung moveable weights, which could be shifted backwards and forwards at will, upon the long arm of the steelyard, arming the short end with a small bar of soft iron. At a short distance beneath this bar was placed another bar of iron surrounded by a coil of fine wire, so that it could be converted into an electro-magnet merely by the transmission of an electric current along the coil. The force of the current, in any given case, then determined the strength of the magnet, and the strength of the magnet was necessarily indicated by the number of grains which its attraction for the short arm of the steelyard could lift, by tilting them up on the opposite long end of the lever. It is only necessary to see this staid and business-like instrument at work by the side of the old ecstatic, as well as astatic needle, to comprehend its superiority at a glance. The one piece of apparatus tossing so wildly and crazily about, that for minutes at a time the most patient and skilful observer can make neither head nor tail of its bewildering movements; the other piece quietly tilting up its weight on the end of the steelyard, and refusing in the most self-possessed way to lift another grain under any inducement that can be brought to bear, and then sending in its refusal as the exact estimate of the force it has been commissioned to determine. This beautiful little instrument was named by its inventor, the Magneto-electrometer.

With these instrumental aids at command, the time now seemed to have arrived for entering fully into the question of the ratio in which increase of distance in a gutta percha covered telegraph wire augments the difficulties of rapid transmission. Many electricians had previously to this time believed that the available force of a current is diminished

in the ratio of the square of the distance it has traversed; that is, that a current which has traversed 600 miles has only a thirty-sixth part of the working force of a precisely similar current which has travelled only one hundred miles. In this part of the enquiry it became essential that the force should be estimated under two perfectly distinct phases, because each is an element in the fitness of the current to accomplish serviceable labour. First the diminution of the current's *power to produce mechanical effects*, in consequence of the length of journey which had been made, was to be examined, and then the *loss of speed* which it experienced from the same cause. If in both these particulars the diminution was in proportion to the law of the squares of the distance, then there could be no doubt that Electric Telegraphy through a long submarine wire, such as the breadth of the Atlantic would require, would become difficult to accomplish in a somewhat similar degree.

A voltaic battery, consisting of 72 pairs of plates, having each a surface 16 square inches, was set to work, and it was then ascertained how many grains the current from this battery would raise in the Magneto-electrometer, upon being transmitted through a wire just long enough to effect the connection. The number of grains lifted was 25,000. The experiment being repeated with the same current transmitted to the Magneto-electrometer through 200 miles of insulated wire, the number of grains lifted was 10,650. With 400 miles of wire it was 3250, and with 600 miles of wire, it was 1400. If the lifting force had diminished in the ratio of the square of the distance through which it had been sent, it would have lifted much less than 1400 grains. It was therefore clear that, in this particular, nature intended to be more auspicious to the cause of Ocean Telegraphy than theory. But this was much more strikingly illustrated when loss of velocity was taken, as the estimate, instead of loss of lifting force. Upon various occasions nearly 5000 observations were made with different lengths of wires, varying from 83 to 1020 miles, with a view to the establishment of the varying rates with which the electrical influence travelled through them. From these observations it appeared that with a length of wire of 83 miles, the transmission was effected in ·08 of a second. With 166 miles in ·14 of a second. With 249 miles in ·36 of a second. With 498 miles in ·79 of a second, and with 1020 miles in 1·42 of a second. Taking 83 miles as the unit, there was in these observations a series of distances employed which would be represented by the numbers 1, 2, 3, 6, and 12. Consequently if the law of the squares of distance had applied, the transmission through the thousand-mile length of wire should have been one hundred and forty-four times as slow as through the 83 miles length, or in other words, it should have required nearly

twelve seconds for its completion. The result of a very large number of direct experiments and observations, pretty well established the fact, that the velocity of movement of a magneto-electric current, through a gutta percha covered copper wire of the size of 16 guage, is 300 miles in from one-twelfth to one-sixteenth of a second; 600 miles in from one-sixth to one-ninth of a second; and 900 miles in from one-fifth to one-fourth of a second. The series of distances being represented by 1, 2, 3—the corresponding series representing velocity becomes $\frac{1}{4}, \frac{1}{9}, \frac{1}{16}$, or thereabouts. With a wire 500 miles long, 350 distinct signals were attainable in a period which allowed of exactly 270 distinct signals, when a wire 1020 miles long was used.

But the extent of the conductor is obviously not the only element concerned in the velocity of transmission, for wires of equal dimensions and of like composition. The velocity varies with the strength or quantity of the electrical current sent through any given wire. Seven small pieces of zinc were prepared and covered entirely with sealing-wax, fragments of copper wire being attached to serve as copper plates. The sealing-wax was then chipped off just from the point of each, leaving a portion of the metal bare, to the extent of scarcely the size of the letter o on this page. These zinc plates having been put into seven small acid-charged cells, and so constituted a voltaic battery, a receiving instrument was set printing by means of their Lilliputian energies, through 600 miles of wire. The printing instrument performed its work with the utmost facility, but by means of the recording apparatus already described, it was proved that the current took nine-tenths of a second to make its journey. From a voltaic sand-battery of twelve pairs of four-inch plates, the current took forty-four hundredths of a second to traverse 600 miles of wire.

Yet again; currents of a different quality travelled with different degrees of velocity, even when equal to mechanical tasks of like amount at the extremity of any given wire. Seventy-two pairs of sand-battery plates (each sixteen square inches in area), which lifted 1400 grains in the Magneto-electrometer at the end of a 600-miles' wire, generated a current which took forty-four hundredths of a second to traverse that distance. Two large double induction coils, 36 inches long, (the secondary coils being composed of a mile and a third of fine wire,) and excited by ten pairs of plates of 100 square inches each, arranged as a Smee's battery, gave rise to a current which could only lift 745 grains at the end of a 600-miles wire, but the current in this case travelled through the entire stretch of wire in nineteen-hundredths of a second. Simple voltaic electricity was capable of a greater mechanical effort at the end of a long wire, than a magneto-electric induced current; but the voltaic electricity, which was capable of the greater mechanical effort, strange

to say, *travelled through the insulated wire at a considerably lower rate of speed.* A very large number of experiments combined to prove that a rate of transmission could be obtained by the employment of magneto-electric currents from 2½ to 3 times as great as that of any voltaic impulse that could be used. The mean or average speed for voltaic electricity in a No. 16 gauge copper wire, of a certain determinate length, was about 1400 miles per second; the mean or average of speed of the magneto-electric current in a similar wire of equal length was about 4300 miles per second. The maximum speed attained by voltaic electricity was 1800 miles per second; the maximum for the magneto-electric current was 6000 miles per second. There could be no doubt after these experiments that the magneto-electric current issuing from induction coils, gives a treble velocity of electrical transmission, and therefore realizes a three-fold working speed.

Professor Faraday has shown that no augmentation of velocity results from the use of an increased amount of battery power in the simple voltaic arrangement, up to the employment of twenty times the number of plates used at the first. In this particular again the double induction current established for itself a marked superiority. This current can have its speed augmented by increased amount of battery power. This was remarkably proved by an inverse inference in one observation, in which there was a steady and gradual diminution of velocity from 5400 to 3600 miles per second, during the spontaneous exhaustion of a small Grove's battery, employed in exciting a series of magnetic induction coils. Increased *quantity* in this arrangement tells by filling the thick wire of the primary coil to its full capacity, and this produces increased polar force in the temporary magnet, and increased inductive excitement in the finer secondary coil. The scientific world is particularly indebted to Professor W. Thompson, of Glasgow, for the attention he has given to the theoretical investigation of the conditions under which electrical currents move in long insulated wires, and Mr. Whitehouse has had the advantage of this gentleman's presence at his experiments, and counsel, upon several occasions, as well as the gratification resulting from his countenance and co-operation as one of the Directors of the Company.

Experiment demonstrates that the velocity of an electric current diminishes with progress along a lengthened gutta percha coated wire, more nearly in the proportion of an arithmetical series, than in that of the squares of the units of distance travelled. The retardation practically *does* in a measure exceed the simple arithmetical ratio of units of distance traversed; but this departure from the law of the simple series is in all probability due to the retardation caused in the further portions

of the conducting wire by the increasingly exhausted condition of the weakened stream. When the amount of electro-motive force is fairly proportioned to the length of the wire, a more uniform rate of propagation in the several parts of a continuous extent is found, than is the case when an inadequate amount of electrical influence is employed.

When the notion was first brought prominently forward that the electrical influence *ought* to pass along telegraphic wires with a velocity proportional in inverse ratio to the square of the length of the wire, an hypothetical plan was proposed for practically getting over this difficulty. This plan was to make the road for the electrical current of easier access, by *rendering it larger*. It was conceived that if one wire was required to transmit signals with equal facility and speed to another which was only one-sixth part as long, the longer wire should be made of at least *six times* the capacity of the shorter one.

It was obviously a matter of primary importance to the cause of Atlantic telegraphy that the deductions of this theory should be put to rigid experimental proof, because if they were correct, so large and ponderous a cable would be required to carry even a single conductor, that the manufacture and deposit in the Atlantic depths of such an unwieldy mass, would be an affair that must prove of exceeding difficulty and cost, if not indeed altogether impracticable. The Calais and Dover cable weighs eight tons per mile; the entire weight of a cable for Atlantic service of only the same dimensions as this, would be at least 20,000 tons. As therefore the Atlantic Cable would be required by theory considerably to exceed this, it is plain that not even Scott Russell's leviathan ship, which will be able to move over the waves with an army of ten thousand men upon her decks, could carry it to its destination. In the unsuccessful attempt to lay down the Mediterranean Cable, it was found to be a task of extreme difficulty, and even danger, to manage the mechanical parts of the operation, owing to the great weight of the cable held in suspension, and the vast strength and grip of machinery required to suspend. It may therefore be easily imagined what the task would be with a cable weighing some ten tons per mile. The weight in Atlantic depths, dependent upon itself, and hanging from the ship and machinery would with it exceed 20 tons; an amount equally inconvenient and dangerous to the cohesion of the structure, and to the capabilities of the apparatus used in paying out.

The first experimental investigations upon this point comprised a series of not less than two thousand observations. The experimenter worked with a 300 miles length of wire, which he was enabled so to double and treble at will, that it became for the time virtually a wire of twice or three times the original capacity. The result was that

it appeared the wire of increased capacity *did not transmit electrical signals with greater facility* and speed than the smaller one. With a length of 166 miles, the velocity of movement of the simple voltaic current came out ·16 of a second for a single wire; ·21 of a second for a double one; and ·28 for a treble one. With the same length, the velocity of the double induction current came out for the single wire, ·08; with the double one, ·09; and with the treble one, ·095 of a second. With a length of 250 miles, the velocity was for voltaic electricity, ·29 and ·406 of a second for a single and double wire respectively, and for the double induction current, ·145 and ·185 of a second. The fact thus actually is, that *increasing the size of the conductor*, *augments retardation* in the transmission of electricity through it. A treble-sized conductor gives nearly a doubled rate of retardation.

The general conclusion drawn from the important investigation of the assumption, that electrical currents would move in submarine circuits with velocities that were in inverse ratio to the squares of the lengths of the circuits, seems to be that Nature recognizes the existence of no such law. "The law of the squares" may possibly apply to the transmission of electricity freely along simple conducting wires, but it certainly does not apply to the case of its transmission along submarine or subterranean gutta percha covered wire, (the facility of transmission being estimated by rate of speed,) because in this the case is not one of simple conduction, but of transmission after the wire has been charged inductively to saturation as a Leyden jar.

It having now been thoroughly determined by direct experiment, that retardation of movement in consequence of increasing distance did not occur at a rate which could seriously affect success, where such an extent as the breadth of the wide Atlantic is concerned; that increased dimensions in insulated marine conductors, augmented the difficulties to be contended with in respect to mere velocity of movement, instead of removing them, so that unwieldy and unmanageable bulk in a long cable, at any rate could never be required; and that by employing the induced magneto-electric current, and reversing the quality of the electricity transmitted at each signal, a velocity and facility of work might be attained in the longest circuits, which would satisfy all mere commercial and financial requirements, in such a line as one crossing the Atlantic;—the conclusion in short having been arrived at, that there was no royal road for telegraphing electricity through the ocean, either upon the base of material bulk in the conductor, or of intensity in the agent, but that the whole affair necessarily resolved itself into one in which symmetry and proportion of arrangements had to be looked to; the well-considered and carefully-

effected adaptation of part to part, of length and size of insulated wire to the amount of work to be done, and of quantity of the agent to the length and size of the wire, and to the necessity of continued reversal and alternation of the currents passed through it.—All this having been settled, it now only remained to *actually record* a signal through two thousand miles of circuit, a length which might be assumed to be about that which would be conceived in the passage of the Atlantic. In the last year, arrangements were made, through the kindness of the Directors of the English and Irish Magnetic Telegraph Company, to secure this final proof. The experiments were planned and carried out conjointly by Mr. Charles Bright, the engineer of the Magnetic Company, and by Mr. Wildman Whitehouse. The underground wires belonging to the works of this Company extend, as has been already stated, from London through Dumfries to Dublin, and they are 660 miles in length. They are also so numerous, and so abundantly connected with ramifications, that a continuous length of not less than five thousand miles can be made up among them. Every possible precaution was taken in the conduct of this trial to guard against incidental causes of error by the introduction of test instruments at each available point of junction; and to crown the whole, the veteran electrician, Professor Morse, of the United States, was present at the operations, and witnessed the result. The whole of the circuit which was employed upon this occasion consisted of *subterranean* or submarine wires. This was the closest approach to the working of a lengthened submarine line which could be obtained, and the arrangements were perfectly satisfactory, because experiment has shown that the conditions which are present in insulated wires placed under the ground and beneath the sea, are strictly analogous, if not actually identical.

On the night of the 9th of October, 1856, the conclave of experimenters met at the offices of the Magnetic Telegraph Company, in Old Broad Street, London, and the hours of ordinary repose were spent in carrying out the investigation which had been planned. The result was an unquestionable triumph. Ten gutta percha covered insulated wires, each measuring more than 200 miles, were connected, so that one continuous circuit of above 2000 miles was formed, the coils of fine wires introduced for experimental purposes at the joints of the wires, further increasing the circuit virtually to the amount of 2300 miles. The magneto-electric induction coils of Mr. Whitehouse were used to excite the wires, and the current was made to operate by means of receiving apparatus, upon one of Professor Morse's ordinary recording instruments. Signals were distinctly and satisfactorily telegraphed through the two thousand miles of wire at the rate of 210, 241,

and upon one occasion, 270 per minute. No more emphatic expression of the importance of the result of this experiment could perhaps be given, than the simple statement of the impression which was made upon the mind of the highly qualified and experienced American investigator, who was present as a witness. Shortly after the trial, Professor Morse wrote to the distinguished friend and advocate of Atlantic telegraphy, Mr. Cyrus Field, in the following words:—"There can be no question but that, with a cable containing a single conducting wire, of a size not exceeding that through which we worked, and with equal insulation, it would be easy to telegraph from Ireland to Newfoundland, at a speed of at least from eight to ten words per minute. Take it at ten words in the minute, and allowing ten words for name and address, we can safely calculate upon the transmission of a twenty-words' message in three minutes. Twenty such messages in the hour; four hundred and eighty in the twenty-four hours; or fourteen thousand four hundred words per day. Such are the capabilities of a single-wire cable, fairly and moderately computed. It is, however, evident to me that by improvements in the arrangement of the signals themselves, aided by the adoption of a code or system constructed upon the principles of the best nautical code, as suggested by Mr. Whitehouse, we may at least double the speed in the transmission of our messages. In one word, the doubts are resolved; *the difficulties are overcome;* success is within our reach; and *the great feat of the century must* shortly be accomplished!"

Towards the close of last year, therefore, the electrical element of wide ocean telegraphy had assumed this phase. Science had then shown:—

That gutta percha covered submarine wires do not transmit as simple insulated conductors, but that they have to be charged as Leyden jars, before they can transmit at all.

That, consequently, such wires transmit with a velocity that is in no way accordant to the movement of the electrical current in an unembarrassed way along simple conductors.

That magneto-electric currents travel more quickly along such wires, than simple voltaic currents.

That magneto-electric currents travel more quickly when in high energy than when in low, although voltaic currents of large intensity do not travel more quickly than voltaic currents of small intensity.

That the velocity of the transmission of signals along insulated submerged wires can be enormously increased, from the rate indeed of one in two seconds, to the rate of eight in a single second, by making each alternate signal with a current of different quality, positive following negative, and negative following positive.

That the diminution of the velocity of the transmission of a magneto-electric current in induction-embarrassed coated wires, is not in the inverse ratio of the squares of the distance traversed, but much more nearly in the ratio of simple arithmetical progression.

That several distinct waves of electricity may be travelling along different parts of a long wire simultaneously, and within certain limits, without interference.

That large coated wires used beneath the water or the earth are worse conductors, so far as velocity of transmission is concerned, than small ones, and therefore are not so well suited as small ones for the purposes of submarine transmission of telegraphic signals; and

That by the use of comparatively small coated wires, and of electro-magnetic induction-coils for the exciting agents, telegraphic signals can be transmitted through two thousand miles with a speed amply sufficient for all commercial and economical purposes.

Upon this electrical basis, the question of oceanic telegraphy was standing when the present momentous year dawned. But the interests of the cause had then been greatly advanced through other agency. The Incorporated New York, Newfoundland, and London Telegraph Company, which had given all the weight of its influence to the stimulation of preliminary investigation, in the summer of 1856, deputed their Vice-president, Mr. Cyrus W. Field, who had indeed been, in the main, instrumental in obtaining the charter from the Government of Newfoundland, to visit England, with a view to the effecting of such arrangements, as were deemed best fitted to advance the undertaking. The consequence of this visit was the formation of the existing Atlantic Telegraph Company, comprising the holders of 350 shares of one thousand pounds each, and having Mr. Bright and Mr. Whitehouse, who had taken such prominent parts in the preliminary proceedings of investigation, as their advising and acting engineer and electrician. The services of these gentlemen were at once secured, in the conviction that in no other way could the success of the enterprize be so materially aided. The charter of the New York, Newfoundland, and London Company, conferring upon it for fifty years the exclusive right to land telegraph cables on the shores of Newfoundland and other parts of North America, and for 25 years to do the same thing on the shores of Nova Scotia, was then made over to the New Company, together with all concessions bearing upon the undertaking which may be hereafter obtained, and all the patent rights of Messrs. Whitehouse and Bright, which in any way concerned the working of instruments in submarine circuits of great length, were prospectively secured to it. In order that the capital subscribed might be entirely applied to the immediate object of the undertaking,

the projectors, Messrs. Brett and Field, and Messrs. Bright and Whitehouse, considerately arranged that their compensation for the privileges assigned, and for past expenditure and exertions should be left entirely dependent on the successful result of the undertaking. The final agreement with these gentlemen was that upon attaining success, a half-yearly dividend of 10 per cent. per annum on the capital should first be paid to the Shareholders, and that then one-half of any further profit should be given to them, and the other half be retained by the Company, it having been estimated upon a very moderate computation of the probable amount of revenue, conjoined with a consideration of the comparatively small working expenses where there can only be two terminal stations to be maintained, that a very satisfactory result might be secured to all parties upon this ground.

It will be seen from the above statement that before the project of establishing an Atlantic Telegraph was brought before the public in a definite form, the ability of electrical science to effect the proposed end had been maturely considered by the projectors, and subjected to the most rigid investigation by direct experiments. There was, however, another element in the project, which it has now to be shown, was no less carefully weighed. A wire of two thousand miles length might be successfully insulated, and made to transmit telegraphic signals from one end to the other. But could a wire of such length be placed in safety in the basin of the Atlantic? Was it within the sphere of fair probability that such a wire could, in the first place, be deposited, and that, in the second place, it could remain where it was laid at rest, and out of harm's way? It fortunately happened that several investigators, prominent among them Lieutenant Maury (the present superintendent of the National Observatory of the United Sates,) and Lieutenant Berryman, —had for a long time been accumulating facts regarding the soundings and currents of the Atlantic. These furnished a very excellent and safe basis for an opinion upon this point, and indeed left very little more to be done than that verifications should be made, and some trifling gaps be filled up. Every care and pains were, however, taken to bring together all the evidence that could be gleaned of the actual state of affairs in the vast oceanic basin, which was to be the scene of the great enterprise, and to collate them with the world-famous labours of Lieutenant Maury, now on record in the sixth edition of his work, "The Physical Geography of the Sea."

Until at a comparatively recent period great difficulty had been experienced in getting any deep soundings in the ocean which could be depended upon. It seemed to be impossible to tell when any heavy weight suspended from a line really struck the bottom on its descent

through deep water. The first step towards a solution of the difficulty was the adoption of the beautifully simple expedient of letting a common cannon ball carry down a length of light common twine, marked off into fathoms, until the ball ceased to unroll the twine off a reel left free to revolve. By the use of this simple plummet, Lieutenant Walsh of the United States Service, made in the deep sea a cast of 34,000 feet without finding any bottom. Lieut. Berryman of the U. S. ship, Dolphin, obtained a like negative result in mid-ocean with 39,000 feet of line. Lieut. Parker of the U. S. frigate, Congress, reported "no bottom" with 50,000 feet of line. Captain Denham of H. M. S. Herald, alone believed that he touched the bottom in the South Atlantic, with a line of 46,000 feet.

It was soon ascertained that the negative results of the above-named, and other similar attempts to find the bottom of the deep sea, were not altogether to be depended upon, because the thin line was carried out into bights or long curves, during the descent of the ball, by currents flowing transversely to each other at different depths, so that the twine often continued to unroll itself from the reel, even when the shot was resting on the bottom of the sea. This and other difficulties have now been entirely overcome by successive improvements in the management of the line, and in the construction of apparatus, especially by the invention of a very ingenious piece, by Mr. Brooke of the U. S. Navy, in which the cannon ball is disconnected from the line on touching the bottom, and a light iron rod alone left attached, to be drawn up with a specimen of the bottom adhering to it, in a cavity prepared at its lower end. The practice in using this deep-sea sounding apparatus is to fasten it to a very strong line prepared for the purpose, and capable of sustaining a strain of better than half a hundred weight, although 600 fathoms of it only weigh about a pound. The cast of the ball is made from a boat, which is kept from drifting by oars, while the descent of the plummet is in progress; and the descent is timed, fathom by fathom, so that the influence of cross currents in drawing out the twine may be allowed for, simply by comparing the rate at which it runs for each given depth, with the rate at which it ought to go. Currents necessarily sweep the twine out at an uniform rate, while the cannon ball as necessarily, on account of increasing friction, drags it out at a diminishing rate, which is accurately known from previous investigation. Thus the motion due to the current can be separated from that due to the descent of the ball. By the employment of this improved plan of sounding, specimens of the bottom are now commonly brought up from the depths exceeding two miles; and from an already very extensive series of soundings, it appears that the

depth of the Atlantic nowhere exceeds twenty-five thousand feet. One of the deepest parts of this ocean seems to be immediately to the south of the banks of Newfoundland, between the parallels of 35° and 40° north latitude.

The basin of the Atlantic is a long trough or groove, indented between the old world and the new, and extending certainly almost from the Northern to the Southern Pole. The hollow of this basin is so great, that the lowest depth of the Atlantic is nine miles beneath the highest peak of the Andes. In most places the actual bottom of the ocean is much broken up and very irregular. Sharp peaks and crested ridges with precipitous sides, there reproduce all the bold alpine contours which are encountered upon the land. The accompanying sketch (Fig. 1, Plate 1) conveys a very good idea of the state of the Atlantic groove, as regards the irregularities and inequalities of its bottom. It represents the actual condition of things between the coast of Africa and Yucatan, and is taken from Lieut. Maury's work on the Physical Geography of the Sea.

Now supposing it to be required that a Submarine Telegraph Cable should be stretched directly from Ireland to the nearest point of the coast line of the United States, that cable would have to be lodged upon just such a support as that represented in the sketch. In places it would have to hang upon lofty pointed peaks, in others it would be bent up and down in zig-zag depths, and in others it would depend from precipitous walls thousands of feet high, continually strained by the influence of its own weight. The direct distance between Ireland and the United States is a little over 3000 miles. Any cable, however, which could adapt itself to the inequalities of the bottom that underlie this route, would probably have to be very much longer than the 3000 miles.

Out in the basin of the Atlantic, in the same parallel of latitude as the coast of Portugal, and about 1500 miles away from Ireland, there is a cluster of supra-marine pegs, upon which an Atlantic Cable might be hung, as an intermediate resting stage. This cluster is constituted by the mountainous islands of the Azores, which are not much more than two thousand miles in a direct line from the coasts of the United States. The idea had occurred that it might prove a very convenient course to make a Telegraphic communication between the British Islands and the United States of America, through the Azores, as there would then be the advantage to each nation of the end of the line being landed upon its own territory. Unfortunately, however, for the prosecution of this scheme, it happens that this cluster of Islands is composed of rugged and precipitous masses which are pierced up from very great depths of the ocean so suddenly, that not a single scrap of shoal coast,

nor a single sheltered bay, is to be found anywhere among them. The Azores are also in the very midst of an area of volcanic disturbance. In their neighbourhood the bottom of the ocean is liable at any instant to be heaved up, and to be broken and crushed with the utmost violence. Besides this, the direct line from the Azores to the United States crosses precisely that portion of the Atlantic which has been alluded to as the one deepest portion of the basin, and which is indeed a vast channel, hollowed out by the hand of Nature for the transmission of that mighty Gulph-stream, which circles as an endless vortex between Africa and Mexico, carrying the heat of the tropics to soften the climate of the more northern realms, and equalizing the irregularities of temperature brought about by uneven distribution of land and sea, and by seasonal variations, but at the same time troubling the tranquillity of the sea wherever it prevails, and introducing movement and mechanical disturbance to a very considerable depth. If 5000 miles of Telegraph Cable were prepared at a cost of nearly a million of capital, and were deposited in this part of the Atlantic, there can be no doubt that the rope would be abraded and destroyed in a very limited period, by the movement and strain to which it would be subjected. If it were carried by the Azores, and one of these islands were used as a relay station, precisely the same dangers and disadvantages would still have to be encountered towards the western end of the route, and there would then be increased risk incident to the volcanic district traversed, which would more than counterbalance the gain of the intermediate resting place; a very problematical advantage in itself, it must be remembered, since that resting place is as far from the United States as Ireland is from Newfoundland. When Lieutenant Maury was consulted by the House of Representatives of the United States, touching the practicability of either of these lines to the United States from England being adopted for telegraphic purposes, his answer was, "These peculiarities of the course constitute obstructions which in the present state of our knowledge, are fatal to such a route."

Under these circumstances, then,—with such a distance of current-encumbered ocean to be traversed, and with such a bottom to be dealt with,—what hope has the extended deep-sea survey furnished, that there is nevertheless a fair measure of probability a Telegraphic Cable may yet be stretched in safety from side to side of this stormy and broken sea? If the attention be fixed for an instant upon the accompanying sketch of the contour of the bottom of the Atlantic, as it extends from the south towards the north, it will be plain what the promise is that the deep-sea survey furnishes. This sketch (Plate 1, fig. 2,) is extracted from Lieut. Maury's "Sailing Directions to accompany the Land and Current Charts."

It will be observed that the Cape de Verd Islands project far above the surface of the sea as sharp and elevated peaks, and that their sides dip suddenly and precipitously down to jagged depths of about 18,000 feet. From this profundity the bottom rises, still in an abrupt way, to constitute the Azores, and then again descends as abruptly to some 14,000 feet. From this, after two or three alternations of rising and falling, it ascends, and then forms a broad even steppe or "Plateau," which after a time again subsides towards the north. This steppe is scarcely 12,000 feet beneath the surface of the ocean, and strange to say, it extends as a continuous ledge 400 miles wide, all the way from Cape Race in Newfoundland, to Cape Clear in Ireland, between the 48th and the 55th parallel of north latitude. This submarine ledge has been very accurately examined by sounding, and it is found that it is nowhere deeper than 12,000 feet (a trifle more than two miles). It dips down slightly from either coast, reaching its greatest depression in mid-ocean; but the slope is a very gradual and easy one, and the surface is devoid of all abrupt irregularities. The general course and contour of this comparatively level submarine track, from the European to the American coast, is represented in Plate 1, fig. 3, a sketch derived from the line of soundings taken by Lieut. Berryman, U. S. N.

The submarine Plateau is really a gently levelled plain, lying just so deep as to be inaccessible to the anchors of ships, and to other sources of surface-interference, and yet not so far depressed, but that it can be reached by mechanical ingenuity without any very extravagant effort. It seems, indeed, that it is a portion of a great zone of table land which entirely engirdles the earth, or which at least stretches from the western side of America to the Asiatic coasts of the Pacific. But what is the character of the surface of this submarine ledge? If it be not broken by furrows and pinnacles, is it nevertheless formed of hard and resisting rock? The deep-sea plummets which have been struck upon it in the course of sounding, come up from the contact, marked by traces of what appears to the eye to be soft white sand. The surface of the plateau is smoothly strewn with a deposit that is as even as the sand of the sea-shore, in many of the tranquil bays of the British Islands.

This superficial covering of the Atlantic steppe is not, however, *sand.* There is no sand in its composition; nothing which seems to have been mechanically abraded and ground, as the siliceous particles have which form true sandy deposits. When it is examined by powerful microscopes, it is found to be entirely constituted of the preserved great coats of myriads of passed-away generations of living beings. The indestructible outside skeletons of little creatures which are known to Naturalists under the names of the "Foraminated" and

"Diatom" races of organization, because the minute shells are, in one case, pierced by delicate holes or *foramina*, through which still more delicate feelers were protruded during the continuance of life; and because in the other case, the creatures during life are multiplied by being "*diatomed*" or cut through into separate halves. These forms are, indeed, the dawnings, so to speak, of vital existence, the one-celled elementary organisms which afford the battle-ground of learned philosophers who are striving to settle the boundary question of the vegetable and animal domains. The accompanying figures (plate 2) contain the portraits of several of these defunct organizations, as they are seen when magnified by the microscope some twenty-two thousand five hundred times. But whence have these interesting little microscopic creatures come to form their sepulchres so far out of the way of the haunts of observers? Have they lived and died where their skeletons now rest? Was this submarine steppe their original dwelling-place? By no means. Professor Forbes has shown that there is no life, either vegetable or animal, two miles down in the deep sea. These minute organisms originally lived in the tropical regions, where the vivifying sun makes the waters as well as the land teem with vital existence, and their siliceous shields have been floated thence in countless multitudes day after day, year after year, and century after century, by the perpetually running gulf stream, and deposited in accumulating heaps just beyond the outer edge of the deep channel of the current, upon this strip of submarine table land *where calm still water only is found.* The presence of this layer of delicate shells on the surface of the Atlantic Plateau, proves beyond all question that the depths are there calm and undisturbed. If a telegraph cable were once lodged upon this impalpable deposit, it would soon be entirely covered over by fresh settlings, even if it did not at once sink into it by the mere influence of weight. If art had prepared a bed for an oceanic cable, after full deliberation, it could not have devised any more complete arrangement than this profound recess of still water, paved beneath with smooth, impalpable powder. It also appears most wonderful to say, that it is in the nature of these dead little Monads to agglutinate themselves round masses of metal, which are buried in their layers. Iron, for instance, upon immersion in sea water, first acquires a slight coating of rust, and this coating then forms a mass of concrete out of some of the elements of the water and these flinty shields, in consequence of the muriate, or some other salt of lime, combining with the oxidized metal. Anchors have been picked up at sea encrusted some inches thick with this spontaneously-prepared concrete. Many excellent authorities in these matters believe, that if a telegraph cable were deposited in this submarine burial ground of the Diatoms, it would not only be in a tranquil and undisturbed retreat,

Shields of the Diatoms and Foraminated Creatures brought up by the deep Sea Soundings from the Telegraph Plateau of the Atlantic.

MAGNIFIED 22,200 TIMES.

Reynolds & Brown Litho, London

but that after a few years it would actually be built in there by a flinty pavement, which no trifling exertion could manage to penetrate;—that, in short, it would not only be at the bottom of the ocean, but would become an integral and permanent part of the ocean bed.

There is no need then for much deliberation on the part of man, as to the exact position the Atlantic Telegraph is to take. Nature has beneficently decided this question for him. Nature, indeed, has made every necessary preparation for the work. Newfoundland is stretched forth as the hand of the New World, to meet the grasp of the British Isles which are extended as the hand of the Old World. Exactly where these hands are held towards each other, and between them, a smooth, softly-paved ledge is laid down, to receive the cord that may compensate for the shortness of their reach, and this ledge is placed exactly at the depth which is required for the security of this connecting cord, and just beyond the edge of the eddying current which troubles the centre of the wide sea. The course of the telegraph cable is precisely marked out by a natural tracing across the depths of the ocean. There is one line, and only one line, in which the work can be accomplished. Providence has designed that the Old World and the New, severed at the first by a great gulf, shall be re-connected by electrical sympathies and bonds, and Providence has prepared the material means for the fulfilment of the design. In his official letter to the United States Legislature, already alluded to, Lieutenant Maury writes—"The only practicable route for a submarine telegraph between the United States and England appears to be along the 'Plateau' of the Atlantic, whereon it is proposed to lay the wire that is now in the process of construction." In accordance with this conviction, and in anticipation of the success which is to be realized, the Lieutenant prophetically christened the transverse table-land ledge of the North Atlantic, "The Telegraph Plateau," even before the completion of the prophecy had become the especial charge of commercial enterprize.

No allusion has been made to the practicability of adopting any course for the telegraphic cable to the north of the 50th parallel of latitude, because no advantage that such a proceeding could ensure, has ever suggested itself. But it may be remarked, in passing, that any attempt to accomplish such a feat, if it had been suggested, must have been at once forbidden by the stormy nature of the sea which would have to be traversed, the entire unsuitableness of the ocean-bed lying beneath, the frequent presence there of huge and deep masses of floating ice, often descending many fathoms down into the water, and grounding and scraping along towards the American shore, and by the inconvenient tract of dreary and wild country which would have to

be passed, before the American end of the cable could be placed in connection with the civilized portions of the continent.

It was not, then, until the matter had been thus deliberately and exhaustively sifted;—until the possibility of transmitting electrical signals through a sufficient length of gutta percha covered wire had been proved by direct experiment, and the existence of a suitable support for the wire across the bed of the ocean had been ascertained by direct observation,—that the project was deemed sufficiently mature for the projectors to come with it before the public. Then, however, the requisite appeal was made. The projectors nevertheless still preferred not to resort to any other steps for the raising of the required capital, than the issuing a simple prospectus to make their wants known, being confident in the obvious excellence of their cause, and, it may be added, their confidence proved to be by no means a fallacious one. In order that a more comprehensive and national character might be given to the undertaking, it was determined that the capital should be divided into one thousand pounds shares, rather than into larger sums, and that all who were inclined to participate in the honor of lending a hand to the grand project, should be invited to subscribe for these shares. The Prospectus was issued on the 6th of November, 1856. In the first week of December of the same year, the whole capital of £350,000 was subscribed for, and a first instalment of £70,000 paid up. During the month of November, negociations were entered into with the Governments of Great Britain and the United States, which issued in their agreeing to engage by contract of twenty-five years duration to pay to the Company, up to the time when its dividend shall have reached 6 per cent., a subsidy of £14,000 a year, and of £10,000 a year subsequently, and to furnish certain assistance in laying the cable down by granting the service of ships. Contracts were now made with the Gutta Percha Company to supply 2500 miles of core, consisting of copper wire, invested by a triple covering of the insulating substance, at £40 per mile, and with Messrs. Newall and Co., of Birkenhead, and Messrs. Glass, Elliot, and Co., of East Greenwich, respectively, for the supply of 1250 miles of the completed cable from each, at the sum of £62,000. These contracts were signed on the 31st of December, 1856. At the present time (July 6th, 1857), the entire cable is completed, with the exception of a small portion of the thick shore ends; above 700 miles have been coiled on board the Agamemnon, at Greenwich, and the Niagara is occupied at Birkenhead with rapidly taking her share on board.

When the practicability of laying down a telegraphic cable in the bed of the Atlantic had been determined, and the resolution had been

taken that the thing which was practicable should be done, it was still felt to be a matter of the highest importance, and possibly one which might in the end involve the question of success, that the mechanical elements of the problem should be as carefully and maturely deliberated upon, and worked out, as the electrical, geographical, and financial elements were to be. It was felt on the instant that there were certain characteristics which the cable must possess, to enable it to meet the peculiar circumstances of the case, and the conditions in which it would necessarily be placed. And it was also known that the arrangements which would be required for dropping the cable safely to the bed of the ocean, would be mainly dependent upon the form and character that were finally given to it on construction. All these matters were therefore to be considered fully, and settled before the terms and details of the contract were presented to the contractors, and before subscriptions were asked for. The very beautiful result which has been the material issue of the deliberation is, in a great measure, it must be stated, due to the science, assiduity, and skill of Mr. Glass, of the above-mentioned firm, to whom the thanks of the Directors are eminently due for his indefatigable exertions.

The first important point which had to be settled, was, what should be the specific weight of the cable? At any rate, it must be heavy enough to go quickly to the bottom of the sea by its own gravity, when launched from the stern of the paying-out vessel. But it must not be *too heavy*, or the loop of some five or six miles, which would have to be sustained between the two vessels at first starting in mid-ocean, would be altogether unmanageable by the appliances at command. The exceeding difficulties which have to be encountered in managing heavy cables out in the deep sea, have been very graphically illustrated in a published communication by Mr. Brett, alluding to an unsuccessful attempt to connect Europe with Africa by a cable of massive construction. After relating that there were only three men at his command whom he found to be brave and trusty enough to be stationed at the breaks, he continues—"I placed these men at the breaks, and they timed the revolution of the drum by a minute watch. It was arranged that the speed of the vessel should never be less than three miles an hour. It was an anxious moment when at midnight we were about to enter the great depths. The changing of the continuation of the cable from the fore to the midships, thence to the upper hold, and finally the removal of the mid-deck, to enable the coil to come up from the lower deck, were operations involving much labour, yet *we dared not stop, lest the perpendicular strain on the cable should be fatal.*" This cable was lost, mainly in consequence of its weight proving altogether

unmanageable, when circumstances necessitated a temporary suspension of the process of laying down in a deep and troubled sea. The cable parted upon a violent plunge of the vessel, and was found to have been broken apparently by friction on the rocks at the bottom, about 502 fathoms (half a mile) from the ship.

But on the other hand, the cable must not be too light, or it would be at the mercy of the currents which it passes through, and share the fate of the twine alluded to in the deep-sea sounding experiments. It would be carried backwards and forwards in a wavy way, instead of going straight on to its destination, the bottom of the sea; and this would happen to the great risk of its integrity, as well as to the great annoyance of the engineers engaged in the work of submersion, as also to the unnecessarily great consumption of rope. If the currents were very strong, the sea very deep, and the cable very light, its strands might indeed be zig-zagged to and fro in the water to enormous distances before it reached the bottom. It is well ascertained that there are in the sea, layers of differently moving water, interposed above each other. In Arctic navigation, nothing is more common than to see a great iceberg plough its way through a floe of field-ice setting down upon its point, and parting right and left in crashing confusion as the frozen mountain presses onwards. The surface ice is, in cases of this kind, carried one way by an upper current flowing steadily in that direction, while the iceberg, with its base sunk, perhaps, to the depth of some quarter of a mile, is impelled the opposite way by an antagonistic or compensating stream running below. Tell-tale icebergs have often been seen, too, moving rapidly towards the North *against a strong southward surface current.* Not unfrequently they make their way quite *across the gulf stream*, instead of going along with it. All this obviously happens, because the specific gravity of these masses of fresh-water ice is such that they are constrained to float seven or eight times deeper in the sea, than they can rear their crests into the air. In Captain Denham's deep-sea sounding, already alluded to, his plummet, consisting of a lead weighing nine pounds, went out the last 706 fathoms at the rate of four-fifths of a mile per hour. The dragging force of so light a weight at that great depth, it is well known, could not produce any effect like this. In this experiment, too, the eighth thousand fathoms of line went out more quickly than the fifth thousand fathoms. It will be plain to all who are initiated in the mysteries of hydrostatics, the nine-pound weight could not be dragging out the rope faster, when that weight was seven thousand fathoms from the surface, than it would when it was four thousand fathoms. The transverse pull of deep conflicting currents, was unrolling the line,

even more than the descent of the lead. It is a remarkable corroboratory proof that the influence of transversely moving currents must have a tendency to draw out into zigzags a line descending through them, that waxing sounding lines invariably quickens their descent; it deprives the moving water of a portion of the advantageous hold upon the hemp furnished by friction. Many instances are on record of lines having been carried away and lost entirely in consequence of the force of under currents acting upon them in different directions at various depths. Such would certainly be the fate of a very light frail cable payed out across the Atlantic in depths of a couple of miles. There are surface currents moving above even the still depths of the "Diatom" covered Plateau. Lieutenant Maury writes, on this subject of conflicting oceanic currents—"A powerful train of circumstantial evidence goes to prove the existence of that system of oceanic circulation which the elements, and the offices, and the adaptations of the sea require, and which its inhabitants, in their mute way, tell us of. This system of circulation commenced on the third day of creation, with the gathering together of the waters which were called seas, and doubtless will continue as long as sea water shall possess the properties of saltness and fluidity."

The cable then was to be made neither so dense, that its weight would render it unmanageable when hung out into the deep sea, nor so light that it would be at the mercy of the currents as it went down. But, also, it was clear that it must not be too bulky, since two thousand five hundred miles of it would have to be stowed and handled. A suggestion, indeed, had been thrown out that bulk was not so much a matter of importance, because a very large cable might be carried out when Mr. Scott Russell's leviathan ship, the Great Eastern, was ready for the service. Before any notion of this kind could be entertained, however, by the projectors, they would have to take well into account that the leviathan ship itself is yet but in the experimental state. This wonderful structure has been very ingeniously planned, and very skilfully built, but it has not yet been *tried.* It must have proved its own armour, before it can be discreet to ask it to undertake a campaign for an ally. It would certainly not be in accordance with the dictates of ordinary prudence and common sense to try two gigantic, and therefore costly experiments, in one, and to associate the fate of an Atlantic Telegraph with the fortunes of an experimental nautical leviathan.

It thus, then, appeared that the bulk and weight of the cable should be such that two vessels of ordinarily large dimensions, and therefore readily obtainable for the service of submergence, could take

the entire cable into their holds, together with the heavier pieces of cable for the shore ends, machinery, buoys, and all necessary apparatus. As each of these vessels would have to carry about twelve hundred and fifty miles of the cable, it became very desirable, if not essential, that the weight of the cable should not exceed one ton per mile.

Again, it was obviously desirable that size, and specific weight being given, the cable should be made as strong as material and dimensions allowed. It could not be *too strong* for its work, although it might be too bulky, too heavy, or too light. Any redundant tenacity that it might possess over and above what was required just for the process of laying down, would only be so much safeguard against possible accidents. It was also important, in the highest degree, that the cable should be flexible enough to adapt itself easily to the curves of the sheaves, and other apparatus employed in the manufacture, and in the process of paying out, as well as to admit of its being readily distributed into coils, while lying in the yard of the factory, and in the hold of the paying-out vessels.

The requirements of the cable may therefore be thus summarily expressed. It needed to be a rope weighing a ton per mile, of such size that it was just so much heavier than the water which it displaced in sinking, as to be carried quickly through the liquid to the bottom, of the greatest strength that could be communicated to it under these circumstances, and of such structure that it could be readily bent, and yet be able to lie in a rigid line. Its centre required to be composed of a wire capable of being made to convey electrical signals through an extent of more than two thousand miles, and capable of retaining complete insulation when immersed in the water of the sea. To find out how all these several essentials might be the most certainly secured and combined, an unrecordable number of direct experiments were tried. While some experimenters were contriving standards of electrical weights and measures, and instituting a detective and coercive staff for the management of the ethereal influence which it was intended to trap and break in for translantic service, others were following out an equally precise and laborious course of enquiry into strength of material, and into the influence of form and composition upon weight and strength. Ropes a little stronger were composed one day, and broken; ropes a little weaker fared the same fate the next. In order to give something like an adequate idea of the pains which were taken with this branch of the investigation, it will suffice to say that sixty-two different kinds of rope had been subjected to the questioning of experiment, and to very close consideration, before the exact form and character of the cable to be employed were determined.

In the cable finally adopted, the central conducting wire is *a strand* made up of seven wires of the purest copper, of the gauge known in the trade as No. 22. The strand itself is about the sixteenth of an inch in diameter, and is formed of one straightly drawn wire, with six others twisted round it; this is accomplished by the central wire being dragged from a drum, through a hole in a horizontal table, while the table itself revolves rapidly, under the impulse of steam, carrying near its circumference six reels or drums, each armed with copper wire. Every drum revolves upon its own horizontal axis, and so delivers its wire as it turns. This twisted form of conducting wire was first adopted for the rope laid across the St. Lawrence last year, and was employed with a view to the reduction to the lowest possible amount of the chance of continuity being destroyed in the circuit. It is improbable in the highest degree, that a fracture could be accidentally produced at precisely the same spot in more than one of the wires of this twisted strand. All the seven wires might be broken at different parts of the strand, even some hundreds of times, and yet its capacity for the transmission of the electric current not be destroyed, or reduced in any inconvenient degree. The copper used in the formation of these wires is assayed from time to time during the manufacture to insure absolute homogeneity and purity. The strand itself, when subjected to strain, will stretch 20 per cent. of its length without giving way, and indeed without having its electricity-conducting power much modified or impaired.

The yielding temper of this strand of pure copper has been a cause for doubt and suspicion to some of the friends of Atlantic telegraphy. It has been anticipated that when the cable is subjected to strain, the comparatively soft core will yield; and that when it yields, it may be drawn out and attenuated to such an extent, that it will have considerably less capacity for transmission of electricity. It has been conceived that when the cable hangs down in the mid-atlantic between the two ships, in a loop six miles long, there will be a weight of six tons hanging upon the points of suspension, and that there will be a consequent strain upon the rope calculated to draw out the ductile copper strand *two feet in every mile*, or twelve feet in the six-miles-loop; and it has been further feared that this elongation of two feet in a mile will necessarily destroy by attenuation all practical utility in the strand for telegraphic purposes. It will be presently shewn that there are obvious reasons why the cable will not be subjected to any such strain as is here supposed. But in order that this fear might be met in the widest way, and so be the most surely set at rest, Mr. Whitehouse devised the following experiment:—He connected three 200-mile lengths of the cable into a continuous line, and then passed a current from two thirty-

six-inch double induction coils, excited by ten Smee's cells, each having plates of 100 square inches of area, through the 600 miles of cable to the magneto-electrometer. The weight of 745 grains was raised on the end of the steelyard, and was thus the measure of the acting force of the current after transmission through the cable. He next made a break in the cable at the distance of 400 miles from the nearer end, and introduced into the gap there one mile of fine insulated wire, which possessed only the one-eleventh of the capacity of the copper strand. This proportion was ascertained by weighing equal lengths of the wire and the strand. The piece of wire weighed three grains, and the piece of strand 33½ grains. A current from the same induction coils was now again passed through the 600-miles length of cable to the magneto-electrometer, with the one-mile length of fine wire interpolated in its course, and 725 *grains were lifted* on the steelyard. Only 20 *grains* of lifting power, out of a force equivalent to 745 grains, had been lost in consequence of the introduction of the mile of fine wire, measuring but the one-eleventh of the central strand! The fear that a stretch of two feet in a mile, for six miles of the cable, would render it electrically unfit for its service, was thus met by showing that if the entire copper strand of the cable *were stretched* 96 *feet in every mile* (an effect practically identical with the introduction of the mile of exceedingly fine wire), the loss of conducting capability would amount to no more than a thirty-seventh part. In addition to this very interesting experiment, it was however also determined that the copper strand bears stretching to 20 per cent. of elongation without having its integrity of texture injured—that is, it may be stretched *one thousand feet in a mile* without being broken, and without its telegraphic utility being materially impaired. It has never broken indeed, until elongated by stretching to the extent of from 25 to 30 per cent. The fact is that this fear of the conducting wire of the cable being telegraphically disabled by attenuation, is based upon the notion that the insulated strand is to act as a *simple conductor*, and not as an *inductively-charged Leyden jar*. It may be, and probably is, true that a simple conductor transmits an electrical current with a facility which is in a measure proportioned to its capacity at the smallest part of its length; the entire conductor being virtually reduced in dimensions to the standard of this smallest part. But it is not true that the transmitting power of an insulated submarine wire, which is virtually a Leyden jar, and open to inductive charges, is modified from the same cause to anything like the same extent. Here the induction, which has taken a mischievous part in producing retardation of electrical movement in coated wires, turns round and makes amends for its interference by causing

small and easily laid wires to be more manageable for submarine telegraphy than larger ones could be.

The copper strand of the cable is rolled up on drums as it is completed, and is then taken from the drums to receive a coating of three separate layers of refined gutta percha; these bring its diameter up to about three-eighths of an inch. The coating of gutta percha is made unusually thick, for the sake of diminishing the influence of induction, and in order that the insulation may be rendered as perfect as possible. This latter object is also furthered by the several layers of the insulating material being laid on in succession; so that if there were accidentally any flaw in the one coat, the imperfection is sure to be removed when the next deposit is added. To prove the efficacy of this proceeding, a great number of holes have been made near together in the first coating of a fragment of the wire, and the second coat has then been applied in the usual way. The insulation of the strand is found to be perfect under these circumstances, and continues so even when the core is *subjected to hydraulic pressure, amounting to five tons on the square inch.* The gutta percha which is employed for the coating of the conducting strand, is prepared with the utmost possible care. Lumps of the crude substance are first rasped down by a revolving toothed cylinder, placed within a hollow case, the whole piece of apparatus somewhat resembling the agricultural turnip machine in its mode of action. The raspings are then passed between rollers, macerated in hot water, and well churned. They are next washed in cold water, and driven at a boiling water temperature, by hydraulic power, through wire-gauze sieves, attached to the bottom of wide vertical pipes. The gutta percha comes out from the sieves in plastic masses of exceeding purity and fineness, and these masses are then squeezed and kneaded for hours by interrupted screws, revolving in hollow cylinders, called masticators; this is done to get the water out, and to render the substance of the gutta percha sound and homogeneous everywhere. At each turn of the screw, the plastic mass protrudes itself through an opening left for feeding in the upper part of the masticator, and is then drawn back as the screw rolls on. The masticators, of various kinds of size and form, scattered about in the room amidst the connected steam machinery, present a very striking and curious appearance to the eye. An object which fancy can readily take to be an old man's full-bottomed wig, just lifts itself up every minute or so from the aperture in the iron cell into sight, as if seeking escape from a prison, and is then relentlessly dragged back into the hole as the screw turns on. When the mechanical texture of the refined mass is perfected by masticating and kneading, it is placed in hori-

zontal cylinders, heated by steam, and squeezed through them by screw pistons, driven down by the machinery very slowly, and with resistless force. The gutta percha emerges, under this pressure, through a die, which receives the termination of both cylinders, and which at the same time has the strand of copper wire moving along through its centre. The strands are drawn by revolving drums between the cylinders, and through the die. They enter the die naked bright copper wire, and issue from it thick, dull-looking cords, a complete coating of gutta percha being attached to them as they traverse the die. Six strands are coated together, ranging along side by side at the first covering. Then a series of three lengths of the strand receive the second coat together. The third coat is communicated to a solitary strand. The strand and its triple coating of gutta percha are together designated "*the core.*"

The copper strand is formed and coated with gutta percha in two miles' lengths. Each of these lengths, when completed, is immersed in water, and then carefully tested to prove that its continuity and insulation are both perfect. The continuity is ascertained by passing a voltaic current of low power through the strand from a battery of a single pair of plates, and causing it to record a signal after issuing from the wire. A different and very remarkable plan is adopted to determine the amount of insulation. One pole of a voltaic battery, consisting of 500 pairs of plates, is connected with the earth; the other pole is united to a wire which coils round the needle of a very sensitive horizontal galvanometer, and then runs on into the insulated strand of the core, whose end is turned up into the air, and left without any conducting communication. If the insulation is perfect, the earth forms one pole of the battery, and the end of the insulated strand the other pole, and the circuit is quite open and interrupted: consequently no current passes, and the needle of the galvanometer is not deflected in the slightest degree. If on the other hand there be any imperfection, or undue electrical permeability in the sheath of gutta percha, a portion of the electricity forces its way from the strand through the faulty places and surrounding water to the earth, a current is set up, and the needle of the galvanometer deflected; the deflection being in proportion to the current which passes, and therefore its degree being a measure of the amount of imperfection. In practice it is found that a small quantity of the electricity finds its way through the coat of the best specimens of core, and produces slight deflection in the needle, although the insulation is yet sufficient for all purposes of telegraphy. There is therefore a degree of deflection which is considered allowable and safe, and it is only when the deflection passes beyond this degree that

the core is condemned. The test for continuity is absolute, but the test for insulation is in a measure relative, and indicative of varying amounts of excellence. A battery of 500 pairs of plates is used for the test for insulation, because it renders the trial more severe. The more intense the electricity is, the more it is likely to force its way through even a slight imperfection in the insulating sheath. During the more recent progress of the work, a very ingenious arrangement has been adopted, which enables the continuity of a cable to be tested by a voltaic current of low power, at the self-same time that its insulation is tried by means of a current of high power. The entire length of cable is joined into a loop, or endless ring. A voltaic sand battery of 500 pairs of plates then has one of its poles connected with the entirely insulated strand of the endless ring, and its other pole with the earth. The circuit is thus insulated, as a whole, and charged as a Leyden jar. But a charged Leyden jar may be made a part of a voltaic circuit; and therefore this charged ring of wire is able to transmit a low-tension current without its charge being in any way interfered with. A small insulated battery of low tension is introduced into, and made part of the circuit, and its low current flows round and round, from pole to pole, through the strand. A bell, also insulated, is so placed in the same circuit, that any break of continuity drops a needle before held magnetically fast, releases some wheel-work, and sounds an alarum. The bell is consequently heard whenever the continuity of the strand fails, and the feeble battery current is arrested. Another bell instrument is so placed as to be rung whenever the 500-cell-battery current acquires undue power, in consequence of faulty insulation allowing it to flow from the endless ring to the earth, instead of being almost entirely imprisoned and retained. The feeble battery which is in the circuit rings the bell *when the circuit is broken.* The strong battery, which is out of the circuit, rings another bell *when an excentric current of a certain amount of force is set up*, by the sheath of the wire or strand not being able to retain its charge.

When about fifty of the two-miles length of core are ready, these are placed in the water of the canal which runs past the gutta percha works, and are joined up by their ends into one continuous strand of 100 miles, the joints being covered with gutta percha. The hundred-mile length is then put through a careful scrutiny in the same way that the smaller portions are tried,—and next it is halved, quartered, and separated into groups of twenty, ten, and finally two miles, and each of these are again separately examined, and tested in comparison with similar lengths previously approved.

During the prosecution of these complicated testings, it has been discovered that temperature exercises a peculiar and altogether unlooked-

for influence upon the insulating power of the gutta percha sheath. A high temperature greatly impairs the excellence of the insulation; but a recurrence of a low temperature immediately restores it to its previous perfection. A coil of the completed cable, which gave only three degrees of deflection in the needle of the galvanometer, as the measure of imperfection, when the thermometer stood at 42 degrees, gave 64 degrees of deflection as the measure of imperfection, when the temperature of the air rose to 59 degrees of Fahrenheit. Mr. Whitehouse remarks that the excellence of the insulation even varies accordingly as the sky is clear or covered with clouds. Sunshine makes the tell-tale needle start out divergently, almost in an instant, and clouds as immediately bring it back towards the neutral line. It is anticipated, and greatly desired, that the bottom of the Atlantic along the line of Lieutenant Maury's Plateau, will be found to possess steadily and unvaryingly about the favourable temperature of 42 degrees. Mr. Whitehouse has collected from his innumerable experiments some very interesting deductions regarding the power of temperature to affect the insulating capabilities of gutta percha, no doubt through the molecular condition of its substance, and has embodied these in a table representing pictorially to the eye the relations of sunshine and cloud, and heat and chill to the readiness of the coated strand to perform its telegraphic functions. It will be at once obvious how favourably this proof of the desirability of a steady low temperature around the coated wire bears upon the question of Marine Telegraphy at large. It is highly probable that the sea will ultimately prove to be by far the best medium in which greatly lengthened wires can be laid.

Whenever separate lengths of the gutta-percha covered core are to be joined together, the gutta percha is scraped away for a short distance from the ends, and these are made to overlap. A piece of copper wire is then attached by firm brazing, an inch or two beyond the joint on one side, tightly bound round until it reaches to the same extent on the other side, and then is there firmly brazed on again. A second binding is next rolled over the first in the same fashion, and extended a little way beyond it, and finally several layers of gutta percha are carefully laid over, and all round the joint by the agency of hot irons. If the core on each side of the joint be dragged opposite ways until the joint yields, the outer investment of the wire unrolls spirally as the ends are pulled asunder, and so the conducting continuity of the strand is maintained, although the mechanical continuity of the strand itself is broken.

The two-mile coils of completed and proved core are wound on large drums with projecting flanges on each side, the rims of which are shod with iron tires, so that they may be rolled about as broad wheels,

and made to perform their own locomotive offices as far as possible. When the core is in position on these channelled drums, the circumference of the drum is closed in carefully, by a sheet of gutta percha, which thus constitutes its core-filled channel a sort of cylindrical box or packing case. In this snug nest each completed coil of core is wheeled and dragged away to be transferred to the manufactory, either at Birkenhead or Greenwich.

The core-filled drums, having arrived at the factory of the cable, the drums are mounted by axles, and kept ready so that one extremity of the length of core may be attached to the cable as it is spun out, when the drum previously in use has been exhausted. During the unrolling of the core from the drum, it is wound tightly round by a serving of hemp, saturated with a composition made chiefly of pitch and tar, the winding being effected by revolving bobbins as the core is drawn along. This hempen serving constitutes a bed for the external coat of metallic wires, and prevents the insulating sheath of gutta percha from being injured by pressure during the final stage of the construction. Each new length of core is attached to the cable by precisely the same operation as that which is used at the gutta percha works in joining the two-mile coils for testing; shortly before an old drum is exhausted, its remainder is rapidly pulled off and placed in the joiner's hands, so that it may be made continuous with the core on a new drum, before the outgoing cable begins to draw upon it. At every turn of the drum the electrical current from a sand battery of a few cells is sent through the core contained upon it, and the cable with which it is continuous, in consequence of the inner end of the core being drawn through the plane face of the drum, and so bared of its insulating covering that the copper strand strikes the metallic support of the axle as it passes, that support being in connection with one of the poles of the battery. If the continuity is perfect, the perfection is indicated by the divergent start of a galvanometer needle fixed in sight above the drum.

When the core has been covered in with its great coat of hemp and tar, and carefully gauged to ascertain the equality of its dimensions everywhere, it is ready to be turned into the completed cable. This final operation is effected as the core is drawn up through the centre of a horizontally revolving wheel or table. The table turns with great rapidity, and carries near its circumference eighteen bobbins or drums. Each of these drums is filled with a strand of bright charcoal iron wire, and has two motions, one round its horizontal axis, and one round an upright pivot, inserted into the revolving table, so that it delivers its strand always towards the centre of the table as it is carried swiftly

round by the revolution. The iron strand is of the same diameter as that which is used for the copper core. There are also seven iron wires in each strand, exactly like those for the copper strand. Eighteen iron strands are thus firmly twisted round the central core, as the "closing machine" whirls. The core, actuated by the rollers of the machinery, rises through the middle of the table, and goes up towards the ceiling. The iron strands dance round it, as it goes up, in a filmy-looking spectre-like cone, which narrows and grows more matter-of-fact and distinct as it ascends, until it glitters in a compact metallic twist, tightly embracing the core. The eighteen strands of seven-thread wire are used for this metallic envelope in place of eighteen simple wires of the same size as the strand, because by this means greater flexibility and strength are obtained for the weight of material employed. The cable would neither coil about so readily as it does, nor resist so much strain as it now can, if it were closed up in solid iron wire of proportionate size in the place of iron strands. The adoption of the strands greatly diminishes the chance of the cable being broken by accident as it is payed out. The hundred and twenty-six fine iron wires present so very slight an appearance that the notion is readily suggested to the eye looking at them, that they surely will soon be eaten away by rust, when they are once immersed in the sea. It has been shown there is some reason to believe that as soon as the rusting process has commenced, it will be stopped by the formation of a natural concrete from the siliceous deposit which exists at the bottom of the ocean. The reliance of the projectors and executors of the work is not however placed upon this natural process of cementation, neither is their trust in the durability of the wire. The fact is simply that the iron investment is only intended to serve the end of protecting the coated core from mechanical violence, and to confer upon the cable a convenient amount of proportionate weight during the process of submergence: it is designed for these purposes, and for nothing further. When the cable is once fairly laid in the still soft depths of the Atlantic, and on its Diatom-strewn shelf, the rust may eat up the iron external coat, as soon as it pleases. There the conducting strand will be as safe as if it were buried in a trench, and the gutta percha covering will be as permanent and durable, in the absence of a high temperature and air, as the gum in the mummy, which lasts unchanged for thousands of years.

Each strand machine works day and night, under the restless energies of steam, and in the twenty-four hours spins ninety-eight miles of wire into fourteen miles of strand. There are several strand machines at work in the factories, and these every twenty-four hours

make 2058 miles of wire into 294 miles of strand. As much as thirty miles of cable have been made in a single day. The entire length of wire, copper and iron, employed in the manufacture, will amount to 332,500 miles, enough to engirdle the earth thirteen times.

As the closed cable is completed, it is drawn out from the wall of the factory, and passed through a cistern containing pitch and tar, and it is then coiled in broad pits in the outer yard (each layer of the coil being again brushed over with pitch and tar), there to remain until embarked on board the vessel which is to convey it to its final home. At both the Greenwich and Birkenhead works, four cables, each three hundred miles long, were simultaneously in process of construction. These will be finally united together into one continuous rope, as the cable is stowed away in the vessel which will carry it to sea.

The completed cable weighs from nineteen hundredweights to one ton, per mile, and bears with impunity a direct strain of four tons being placed upon its strands. Some pieces have borne a direct strain of more than five tons without breaking. When, however, the cable is immersed in sea water, its relative weight will, of course, be diminished. Its downward pressure in salt water will be a little under fourteen hundredweight per mile. The greatest depth over which the vessels will have to pass in depositing the cable in the Atlantic, will be a little more than two miles; consequently if enough of the rope were suffered to hang motionless from one of the vessels to reach the bottom in this depth, the strain needing to be borne by the rope would be under a ton and a half. During the process of paying out, however, the cable will be constantly in motion, with only a sufficient restraining power upon it to control and regulate its egress from the ship, until this is by a rate slightly faster than the progress of the vessel. The strain will hence really be considerably less than a ton and a half for two miles. Here again another modifying influence also comes into play, to act still further in the relief of the strain. The cable will not only be somewhat buoyed up, so to speak, by the water, it will also be buoyed up by the influence of friction. It will never descend, as it is payed out, in a vertical line, or reach the bottom in a course even approaching to a perpendicular direction. This will be because friction of the sides of the cable against the water will retard the sinking of the mass. The amount of this retardation, and the length which will consequently lie between the stern of the vessel and the bottom of the sea, will be determined by the rates at which the cable is payed out, and at which the paying-out vessel moves. In real fact, so far from there being any strain, consequent upon the weight of the cable, sufficient to injure its integrity, there will be only just pull enough to

drag it gently out of the vessel over the revolving sheaves. The strain will be like the strain which is put on the filmy thread of the silk-worm, as it is reeled rapidly off from the cocoon, and not like that which is put on a fixed rope, when a heavy weight is hung freely upon its lower end. The buoyancy and friction which will hinder the cable from dropping directly to the bottom of the sea, will sustain and uphold it as it falls. The specific gravity of the cable, and its flexibility, have been so planned that it will be laid down at the bottom of the ocean as gently as if it were passed through men's hands, or over pulleys all along its course in the yielding water. The frictional influence which will thus "lend a hand" to deposit the Telegraph Cable in the Atlantic, is identical with the cause of the regularly progressive diminution of the speed of the plummet's descent in deep-sea soundings, already alluded to in speaking of the method employed for eliminating the horizontal pull of diversely moving currents, from the vertical drag of the plummet. There is, however, one important difference between the case of the cable, and that of the sounding plummet. The plummet drags down a line which is lighter than the water, and which therefore has more buoyancy than friction attaching to its movement. The cable is altogether heavier than water, and has more friction than buoyancy. Friction will produce more retardation, comparatively, in the movement of the cable, than in that of the sounding plummet and line.

If the plan of paying-out be adopted, which will start the "Agamemnon" and "Niagara" from each other, opposite ways, in the Mid-Atlantic, about ten miles of the centre of the cable will be encased in a sheath of eighteen steel wires of No. 13 gauge, which will here take the place of the iron wire strands. This part of the cable is designed to meet the higher amount of strain incident to the first step of deposition in this fashion, and it is strong enough to withstand a direct strain of as much as twelve tons. The ends of the cable will also be of augmented dimensions and of immensely increased powers of resistance. Ten miles deposited on the coast of Trinity Bay, and fifteen miles resting off the coast of Ireland, where there will necessarily be some slight risk of injury from anchors and surface interference, will be an inch and a half in diameter, and will weigh more than seven tons per mile. This part will be encased by twelve solid charcoal-iron wires of No. 1 gauge. The No. 1 wires will pass gradually into No. 2, and No. 2 into No. 3, as deep water is reached. The strong ends thus taper gradually through about half a mile into the main cable. The gutta percha casing and serving of tarred hemp are also thicker upon these "shore ends" as well as the outer iron coat.

It has not been deemed necessary, in planning this cable, to provide any wire for the return current of the circuit. The reason is plain. In every telegraph yet brought into use, the earth itself has been found sufficient for the completion of the circuit, a return wire therefore cannot be deemed absolutely essential. The addition of a second, convenient though unessential wire, would, if it were made without any diminution in the amount of insulation, have added very largely both to the size, weight and expense of the cable, and in all probability on account of the additional time required for the manufacture, would have unavoidably deferred the completion of an Atlantic Telegraph to another year. So long as the notion is maintained that the so-called electric current is a real pouring along of a subtile ethereal agent, the mind clings to the idea that a return course must be provided to bring back to the battery that which has been sent out from it. But the instant the more rational conception has been realized that the so-called current is nothing more than a transmission along the material conductor of a disturbed and alternating movement of its constituent molecules, and that the earth is merely a vast reservoir of neutralization for this molecular disturbance, enabling the constrained state of particles to be relieved when contact with it is made, and so the susceptibility for a like kind of disturbance to be restored;—the instant this conception is matured, it becomes apparent that no return course is really required. All that is requisite is that each pole of the excited battery should be placed in communication with the great neutralizing reservoir, the earth, in order that the states of tension and repose may be able to succeed each other; without such contact, tension continues, and as transmission of the influence is rapid transition from tension to repose, and from repose to tension, there is consequently no current.

At the present time the cable is being stored away in the vessels, which have been provided to float it out into the Atlantic, a work that necessarily occupies a considerable period, although not less than forty or fifty miles are disposed of in each vessel every day. The British Government placed at the service of the Company the fine 91-gun line of battle ship, "Agamemnon," the same which carried the flag of Admiral Sir Edward (now Lord) Lyons in the Black Sea, before it was transferred to the "Royal Albert." The American Government munificently sent over to bear its share in this national work, its splendid new frigate, the "Niagara," a Leviathan in powers of mischief, but of course making its graceful appearance on this occasion without its teeth. An article in "Harper's New York Weekly Journal of Civilization," sagaciously and pleasantly remarks on the august companionship so soon to be entered upon by these noble vessels in their labour of love,—"What a satire

this work will be upon those warlike armaments! How it will put great guns, and cutlasses, and boarding pikes to shame! Gallant Jack Tars of the old time, will have to see that their vocation will henceforth be gone. What would Nelson and Collingwood have said of meeting a foreign first-rate in mid-ocean *to lay a cable* at the bottom of the sea!" The "Agamemnon" proves to be admirably adapted, by her very peculiar construction, for the service of receiving the cable. The engines of this ship are situated very near the stern, and amidships there is a magnificent hold 45 feet square, and some 20 feet deep, between the lower deck and the keel. As the observer stands in this vast space, and looks round, it is hardly possible to believe that he is actually within a floating vessel. In this capacious receptacle the half of the cable is being distributed round a central core, in a compact single and nearly circular coil. The "Agamemnon" is moored off the wharf of the works at Greenwich, and the cable is drawn to its hold by a small journeyman steam-engine of twelve-horse power; the rope running over sheaves borne aloft upon the masts of two or three barges, so moored between the wharf and the ship as to afford intermediate support.—The "Niagara" was not, by original construction, so convenient for the purpose to which she has been commissioned. There is no clear space in her hull where her half of the cable can be packed into a single circular coil. By the considerate kindness of her officers and the courtesy of the United States Government, other difficulties and inconveniences have been overcome; a portion of the fine ward room has been temporarily given up for the accommodation of the exacting guest, and every removable obstacle which could have prevented the cable from being stowed in the best possible manner, under the circumstances, has been got rid of. It is a matter of especial congratulation to the Directors that through this courtesy and kindness they are saved the deep regret which they would have felt, if this noble ship had not taken her proper place in the work of depositing the cable, after she had been so considerately sent across the Atlantic for the purpose. The "Niagara" is now at Birkenhead taking in her share of the burthen, four distinct coils being distributed fore and aft.

The entire extent of the plateau upon which the cable will have to lie, was carefully surveyed some time since, by Lieutenant Berryman of the United States Navy, and sounded throughout its entire length at regular intervals with Brooke's deep-sea sounding apparatus. The range of the Plateau, and its form, are indeed mapped down with considerably greater accuracy than the interiors of the Continents of Africa or Australia. Commander Lieutenant Dayman has, however, been recently sent out in H. M. S. "Cyclops" to check Lieutenant Berryman's soundings, and is now in the Atlantic, prosecuting the

labour. It is expected that by the close of July the two vessels will have their respective portions of the cable on board. They will then rendezvous at Cork harbour, and final arrangements having been there made, will proceed in company to sea, piloted, and assisted when necessary by the United States frigate, "Susquehanna," and H. M. frigate, "Leopard," both paddle-wheel steamers of great power.

The time for the completion of this enterprise by the deposit of the cable in the ocean, has been determined by the same exertion of patient investigation and deliberate thought, which has characterized every other part of the proceeding. Lieutenant Maury has collated observations made in the Atlantic during 260,000 days to ascertain the precise time of the year at which the state of the Atlantic is most favourable for the prosecution of the work of submergence. The result of the laborious investigation of the Lieutenant shows that during summer the western part of the route of the cable is entirely exempt from gales, and that in June and July the risk of gales in the eastern part is very small, becoming almost annihilated in August, excepting just on the coast of Ireland. The western side of the route is, however, more liable to fogs than the eastern, especially in June. Ice is met on the course which will have to be followed less frequently from June to August, than at any other season, the frequency diminishing from June to August. If fogs alone were the obstacles to be avoided, the winter months would be better for the work than the summer months. If ice were the chief danger, then August would be the best month. If storms were most dreaded, then the month of June. Taking ice and fogs and storms all into consideration together, Lieutenant Maury has come to the conclusion that "between the 20th of July and the 10th of August, both sea and air are usually in the most favourable condition for the laying down of the wire." Accordingly the vessels will be so dispatched as to reach the mid-points, where the opposite halves of the cables will be joined, as soon after the 20th of July as can be accomplished.

The course which it is best the vessels should take while dropping the cable, has also been very maturely and carefully considered. The arc of the great circle, which lies between the mid-entrance of Trinity Bay, designed to be the western terminus of the cable, and the mid-entrance of Valentia Harbour, in Ireland, the eastern terminus, is 1834 miles in length, and the central point of the arc is situate in latitude 52° 4′ N., and in longitude 32° 32′. The nearest course for the vessels would obviously be to keep constantly in this arc of a great circle, and so to pass along the earth's curvature direct from the one point to the other. In practice, however, this is a task which not even the skill of

modern navigation can accomplish. In order to effect it, the course of the compass-steered ship would require to be altered by an almost inappreciable quantity at every instant. Unavoidable errors and accidental perturbations of the magnetic needle, deviations resulting from false steerage, bad reckoning and caprice of oceanic currents, all combine to render it absolutely impossible that a ship should be kept by human agency in the fine track thus marked out by theory as the nearest road. The best thing that can be done, under these circumstances, is obviously to make as near an approximation to the impracticable task as is consistent with the appliances science has placed in the hands of the navigator. A vessel can be steered with tolerable certainty within a quarter of a compass-point of the direction in which it is desired it should go. If therefore a route be marked out across the Atlantic, in which the outline of a polygon is transcribed along the earth's curvature, the polygon being such that the change of direction in passing from side to side of the figure is never more than a quarter of a point of the compass, then that route will be the closest approach to a great circle that a skilful seaman can compel his ship to keep. Lieutenant Maury has made a very elaborate calculation to determine a polygonal route of this character between Valentia Harbour and Trinity Bay, and he has laid down a course in which a vessel may pass from one point to the other by only changing the direction of its movement six times, upon each occasion to the extent of a quarter of a point, and which really deviates so slightly from a true great circle track, that if the "Agamemnon" and the "Niagara" sailed from Ireland to Newfoundland at exactly equal rates, the one being carried along the true great circle, and the other moving in the prescribed route, *neither would be out of hail of the other*, from the beginning to the end of the voyage. The distance by Lieutenant Maury's polygonal course will only be eight-tenths of a nautical mile greater than the distance along an exact great circle of the earth's surface. If the telegraph cable were laid evenly in this polygonal track, and were then hauled taught into a true great circle arc by means of windlasses at each end, each windlass would only have to haul in about 350 fathoms of the cable.

It has been stated that the distance over which the cable will have to extend is 1834 miles in length. It is an illustration of the exceeding care which has been taken to provide against every possible accident that an allowance of a superfluous length of more than 600 miles has been made, beyond the quantity which will be required just to fill this direct polygonal track. It will be seen how liberal this allowance is, when the statement is made that only three miles and three-quarters of cable were required over the direct distance between the terminal stations,

when the Varna and Balaclava rope was submerged, although the submergence was effected during a storm. The superfluous allowance made in the case of the Atlantic cable amounts to 33 per cent. of the entire distance to be traversed, without including the 25 miles of shore ends.

Valentia has been chosen for the eastern terminus of the cable, not only because it is the point in which the British Isles make their nearest approach to the shores of Newfoundland, but also because it is remarkably fitted for the distinction which has been marked out for it. It seems indeed as if the hand of the Old World, which is here stretched out to the furthest towards the extended hand of its western neighbour, the New World, actually had its finger raised in invitation of the desired communication. There are several sandy coves in the neighbourhood adapted for the landing or attaching of the cable; and a conspicuous hill, the Great Skellig, with a light-house on its summit, towers up to a height of 700 feet at a short distance from the shore. The shore itself sinks into 420 feet water within fifteen miles of the coast, and along this fifteen miles of shoal space, there is no anchorage frequented by ships.

When the Agamemnon, the Niagara, and the paddle-wheel consorts of these vessels, have joined company off Cork, the entire length of cable will be temporarily joined up, to be tested through its entire length, and in order that a few brief experiments may be made, to prove the efficiency of the signalling apparatus, and its adaptation to the work which will have to be performed. The Agamemnon and Niagara will then start off into the Atlantic with their burthens, preceded by their respective attendants, which will be engaged in sounding as they go. Whether the respective vessels will proceed into mid-ocean with unbroken bulk, join the ends of their halves of the cable in a spot midway between the 32nd and 33rd meridians of west longitude, and a little north of the 52nd parallel of north latitude, and then move asunder, the Niagara with her bows towards the west, and the Agamemnon looking towards the east;—or whether the shore end will be attached to Valentia bay, and the Agamemnon will pay her share of the cable out on her westward progress, the Niagara joining on when her consort has completed her part of the labour, is not yet determined. The point is at present under the consideration of the authorities who are most competent to arrive at a safe and satisfactory resolution in the matter. The cable, however, when once in the act of being laid in the ocean, will come up from the hold of the ship, sweeping round a central block or core, which is planted in the midst, to prevent any interference of the unrolling strands with each other,

or too sudden turns which might twist the cable into kinks; having reached the open space above the deck, it will wind out and in, round four grooved sheaves, geared together by cogs, and planted so firmly on girders, that it is next to impossible they should be thrown out of the square. The grooves in the sheaves will be accurately fitted to the form and diameter of the rope. From these sheaves the cable will proceed three or four feet above the poop-deck, until it passes over a fifth grooved sheave standing out upon rigid arms over the stern. From this it will make its plunge into the deep still sea, dragged out as the vessel moves away by its own weight, and by the hold which it will have acquired upon the bottom of the sea. The paying-out sheaves will be large grooved drums, five feet in diameter, and set in a vertical plane, one directly before the other, and they will have a friction drum geared to them in such a way that its shaft revolves three times as fast as theirs, the axis of the drum being encircled by two blocks of hard wood, which can be gripped close upon its circumference by screw power, so as either to retard or arrest altogether the movement of the sheaves. The screw will be worked by a crank, at which a trustworthy officer will be stationed, the chief portion of whose duty it will be to keep a wary eye upon an electrical indicator stationed near at hand, which has been so contrived that it will express the exact amount of strain thrown upon the cable at each instant. This machinery has been made with remarkable precision and excellence by Messrs. C. de Bergue and Co., of Manchester. In the electrician's department there will be signals every second by electrical currents passed through the entire length of the cable, from shore-end, or from ship to ship. At the side of the vessels there will also be patent logs hanging down into the water, with vanes and wheels turning faster or slower, according to the velocity with which the ship drags them through the water. One of these wheels, in the immersed log, has been so arranged as to make and break an electric circuit at every revolution, a gutta percha covered wire running up from the revolving wheel unto the deck of the ship, so that it may carry the current whenever the circuit is made, and record there, upon a piece of apparatus provided for the purpose, the speed of the vessel. The breaksman will watch the tell-tale which indicates the strain on the rope, and will work his crank and loosen his grip whenever this seems to be too great; or he will tighten his grip if ever the bell ceases to report that the electrical way from end to end of the cable is free and unimpaired. The electrical log is mainly due to the ingenuity of Mr. Bright. This gentleman's calculations, by anticipation, fix from four to five miles an hour as the rate at which it is desirable the paying-out vessel should move. The precise line in which the cable will fall to

the bottom of the sea, and the length which will lie between the stern of the ship and the Plateau-shelf for any given depth, will principally depend upon the speed of the vessel's movement. It is quite impossible that any one should at the present time say what the exact contour of the descending rope will prove to be.

An external guard has been placed over the screws of the vessels to defend the cable from fouling in case any necessity should arise for backing the vessels. The Agamemnon has been jury-rigged for the service; that is, has had its heavy masts and rigging removed, and lighter spars and ropes substituted, to render it steadier and more certainly manageable under steam. Every possible contrivance has been adopted that seems calculated to secure the successful issue of this wonderful feat of depositing eighteen hundred miles of metallic rope unscathed, and almost unscratched, at the bottom of a deep sea. But the hope of the future goes considerably further than this. It is even more firmly based upon the arrangements which have been made to meet and obviate any chance difficulty or obstacle that may arise at a moment's warning. These interesting arks laden with the as yet ungerminated seeds of future connection between the East and the West, will go to sea, prepared, so far as human ingenuity and skill can be spoken of as making preparation where a Superhuman Power alone rules, to convert failure into success. They will carry in their cabins, and upon their decks, every implement and appliance which forethought has indicated to be necessary for at once repairing casual imperfections or accidents. It has been stated that a recording bell will sound every second to indicate that the channel of electrical communication is unimpaired, and that all is going well. Suppose that an ominous and unwelcome silence should fall upon the clapper of this tell-tale, and warn the listening officers that a screw is loose somewhere, on the instant the vessel will be backed to slacken the cable, the brake will be bound down on the friction drum to arrest its out-run, and if necessary, the rope will be shifted to a pair of large many-grooved sheaves, standing ready at hand, and turned backwards and forwards over them until a sufficient grip has been secured, and then they will be set rolling by a steam-engine prepared for the work, gathering back the slack rope as the vessel moves astern, the electrician all the while testing and scrutinizing its insulating continuity yard by yard, until the faulty place is discovered. The imperfect portion will then be cut out, and the gap be supplied by joining up the ends of the uninjured part, and the paying out and testing will be resumed as at the first.

But suppose that the difficulty encountered should be some violent and inconsiderate hurricane, sweeping across the face of the Atlantic

at an unwonted season, and altogether uninstructed, or unsympathizing, in the needs of submarine telelegraphic engineering, what then is to be done? Readers will have heard, many times and oft, that one of the resources of the sailor trapped by a gale in some inhospitable and unfavourable roadstead, is to slip his anchor. What will they think when told that the resource of the telegraphic expedition under especially unfavourable circumstances, will be to "*slip the cable!*" In the unsuccessful attempt to cross the Mediterranean with a telegraphic communication, it will be remembered the cable "slipped" itself upon the occurrence of a tempestuous sea, and was never again recovered for any serviceable use. The voluntary "slipping" of the Atlantic cable in case of a heavy storm, would, however, be altogether another kind of affair. There are ready prepared upon the decks of the paying-out vessels, two large reels each wound round with a very strong auxiliary cable, composed of iron wire only, and capable of resisting a strain of ten or twelve tons. Of this auxiliary cable there are about two miles and a half on each reel. In the ordinary course of the paying-out proceedings, these reels, will look very much like lazy and useless supernumeraries, which have no office to perform. In case of dire need, however, they will be pressed into service, and become the main stay of the operations. Should such heavy movement occur in the huge vessel as became threatening to the integrity of the precious freight, the telegraph cable would be divided, and the sea end would be securely attached to one of the strong supernumerary cords stored upon the reel. Then this would be let rapidly out, and the telegraph cable would be so lowered to the still depths of the ocean which are impenetrable to storms, there to be in calm security until the danger was past. The entire strain of the tempest would thus fall upon the suspending supernumerary, made of a calibre equal to the task. And even this strain would be soon lessened, for the upper extremity of the rope would be attached as quickly as possible to buoys, possessing something of the form of the quill flôat of the angler's line. These elongated buoys being tossed over-board, the ship would hold on its course before the storm, and the elongated buoys would bob lightly and easily up and down in the stormy waves, almost without the strand at the bottom of the sea being affected by the disturbance. When the tempest had blown by, the vessels would return and pick up the buoys, and then proceed to recover the cable, and the work would be so resumed under a more propitious sky.

A very curious picture is presented to the mind when those two noble ships are thought of, increasing their distance from each other on the ocean by miles every hour, should the plan of paying out opposite

ways from mid-ocean be adopted, and the inmates of either of them still discoursing with their co-laborateurs in the remote vessel continuously with almost as much facility as if they were within ear-reach. The picture is not the less interesting when it is remembered that that conversation will be of a very serious and matter-of-fact nature. Experiments will be constantly tried by currents of electricity transmitted through the cable, as the vast distance between the ships, or under the other alternative, between the ship and the land, augments more and more, which will tend to throw considerable light on matters vitally connected with the ultimate working of the telegraph. The power of the earth's magnetism inductively to set up currents on its own account, in so extended a line of insulated wire stretching east and west, and so to pre-occupy the cable to the exclusion of the public service, and in utter disregard of the Company's fees, will be particularly examined with a jealous scrutiny. It is within the bounds of possibility that this perturbing influence of terrestrial magnetism, especially during the occurrence of magnetic storms, may prove to a certain extent, troublesome. It is so, even on shorter circuits. The superintendent of the magnetic and meteorological department of the Royal Observatory at Greenwich, Mr. Glaisher, not unfrequently finds indications of the coincidence of such magnetic disturbance with failure in the service of certain lines of electric telegraph. He tells of the editor of a provincial newspaper who suspected the officials of a telegraph of being in league against him, to withhold certain information which he required, when the Greenwich self-registering instruments were recording on their paper a perfect tornado of magnetic oscillations, looking on their linear and tabulated sketch, like some wondrous Alpine land of jagged peaks and abrupt valleys. Mr. Whitehouse is at the present time deeply occupied with this question, and it will be deemed a very satisfactory assurance that he is quite convinced, should any difficulty of this nature occur, he shall have it finally under complete control, by merely ascertaining the quality and amount of the earth-induced charge, and then immediately neutralizing and destroying it, by sending into the wire a charge of the opposite kind and of equal power. He is already arming himself against the intrusion of these electrical vagrants into the private roads and bye-ways of the Atlantic Company, and there can be no doubt will be ultimately found equal to their instantaneous expulsion whenever they appear.

If no cause of delay occur during the process of laying out of the cable, and if the anticipated speed of five miles an hour on the part of the vessels is reached and maintained, it is possible that the entire cable may be in its final resting-place at the bottom of the ocean in two

or three weeks after the sailing of the expedition. At any rate, it is confidently anticipated that within a month, a message will be flashed from the shore of Trinity Bay to the Shore of Valentia harbour, through the entire length of the cable, to intimate that the project of Atlantic Telegraphy has become an accomplished fact, and that the New World has bound itself by a new bond of intimate alliance with the Old.

Three gentlemen have been intimately associated with the engineer in chief in the work connected with the preparations for laying the cable; all of them individuals who have previously won laurels in the field of submarine telegraphy. These gentlemen are, Mr. Canning, who successfully submerged the Newfoundland cable, and who has also deposited several others at the bottom of the sea; Mr. Woodhouse, who effected the telegraph communication between Varna and Balaklava during the Russian war; and Mr. F. C. Webb, who has had charge of the line belonging to the Electric Telegraph Company, which works from Orfordness to the Hague. The actual manufacture of the paying-out machinery, arranged by Mr. Bright, has been carried on under the superintendence of Mr. Henry Clifford, whose experience and talent in mechanical engineering has proved of great service to the Company.

When the Atlantic cable is in position at the bottom of the sea, telegraphic signals will be transmitted through it by induced magneto-electric currents, on account of the superior velocity this kind of electricity possesses over the voltaic stream, as has been already explained. These currents will be called forth by a somewhat complicated agency, the primary element in which will be a voltaic combination of a very novel and ingenious kind.

The primary source of the influence which will be charged with the service of Atlantic Telegraphy, will be a giant voltaic battery, of ten capacious cells, which may be appropriately termed, the "Whitehouse Laminated or Perpetual Maintenance Battery," on account of the one marked peculiarity which especially fits it for the employment it is designed for. This battery is made upon the Smee principle, so far as the adoption of platinized silver and zinc for its plates is concerned; but it differs from every form of combination that has hitherto been in use, in having the plates of each cell so subdivided into subordinate portions, that any one of these may be taken away from the rest for the purpose of renewal or repair, without the action of the rest of the excited surface of the cell being suspended for a single moment. The battery, in fact, may be entirely renewed a hundred times without its operation having been troubled with even a passing intermission. So long as a fair amount of attention is given to the renewal of its zinc element piece-meal, it is indeed literally exhaustless and permanent. This very desirable quality

is secured by a singularly simple and ingenious contrivance. The cell itself is formed of a quadrangular trough of gutta percha, wood-strengthened outside, in which dilute acid is contained, the proportion of acid to water being one part in fifteen or sixteen. There are grooves in the gutta percha into which several metal plates slide in a vertical position. These plates are silver and zinc alternately, but they are not pairs of plates in an electrical sense. Each zinc plate rests firmly at the bottom on a long bar of zinc, which runs from end to end of the trough, and thus virtually unites the whole into one continuous extent of zinc, presenting not less than two thousand square inches of excitable surface to the exciting liquid. Each silver plate hangs in a similar way from a metallic bar which runs from end to end of the trough above, the whole of the silver being thus virtually united into one continuous surface of equal extent to the face of the zinc. The zinc does not reach so high as the upper longitudinal bar, and the silver does not hang down so low as the inferior longitudinal bar. The battery is thus composed of a single pair of laminated plates, although to the eye it seems to be made up of several pairs of plates. Nature has set the example of arranging extended surface into reduplicating folds, when it is required that such surface shall be packed away in a narrow space at the same time that a large acting area is preserved, in the laminated antennæ of the cockchafer. These antennæ, indeed, are the types of the Whitehouse battery. If any one of these reduplicated segments of either kind of metal is removed, the remaining portion continues its action steadily, the effect merely being the same that would be produced if a fragment of an ordinary pair of plates were temporarily cut away. The silver laminæ are of considerable thickness, and securely "platinated" all over; that is, platinum is thrown down upon their surfaces in a compact metallic form, and not in merely the black pulverulent state; consequently they are almost exempt from wear. Each zinc lamina is withdrawn so soon as its amalgamation is injuriously affected, or so soon as its own substance is mainly eaten away by the action of the chemical menstruum in which it is immersed, and a freshly amalgamated, or new zinc lamina, is inserted into its place. The capability of the piece-meal renewal of the consumptive element of the battery in this interpolatory and fragmentary way, is then the cause of its "*perpetual maintaining*" power.

The perpetual maintenance batteries which will be actually used in the working of the Atlantic Telegraph have been in operation for some time, and are found to answer the expectation entertained of some by their contriver in the fullest degree. They are steadier in action, and occasion less anxiety and trouble to the attendants than any other

kind of battery that has ever been brought into play; and they are of exceeding power. When the large wire ropes, or broad strips of copper-plate, which are connected with their poles in the place of the ordinary uniting wire, are brought together and separated, brilliant flashes pass between them, accompanied by an abrupt and loud crackling sound. In one experiment tried to determine the heating capability of the ten cells, half an inch of the extremity of a large pair of pliers was red hot in five seconds after it had been pressed by the separated ends of the polar appendages, and several spires of a common iron screw, one-quarter of an inch thick, were in the same condition in a slightly longer time. A very remarkable illustration was afforded of the power of the human body to resist the passage of electrical currents of low intensity, upon this occasion. Having seen the effects produced upon the half-inch of iron, in the case of the pliers and the screw, when they were placed in the interruption of the circuit, the writer of these pages substituted his own body for the iron, by taking one of each of the continuation poles of the battery in either of his moistened hands. No sensation was experienced, but a galvanometer, placed in front of his chest, indicated that just a slight stream of the electrical influence did force its way through his person, the needle of the galvanometer being deflected from its position of neutrality by a few degrees. This part of the experiment furnishes a very simple illustration of the difference between quantity and intensity in electrical agencies. *Quantity* depends, in a voltaic combination, on the extent of surface which is exposed to chemical action in each pair of plates; and the heat produced in any given portion of the conducting circuit, or better still, the amount of water decomposed when similarly situated, is the approximate measure of that quantity. In the case of the Atlantic battery, the quantity of electricity generated, and the heat developed is very great, because there are two thousand square inches of each of the metallic surfaces under excitement in each cell. But notwithstanding the great quantity of electricity thus generated and made available, that quantity is of such low intensity, that it is unable to strike its way, as intense lightning really of much *less quantity* would, through the human frame. The *intensity* of a voltaic arrangement depends upon the number of its pairs of plates, or cells. If in the experiment the intensity of the electricity had been increased, without any alteration of quantity, merely by multiplying the number of the cells engaged, or by some analogous modification of instrumental agency, the body which resisted the current of the battery with such complete effect, would have been flashed through and burnt up, like the fragment of metal that had inferior powers of resistance.

The flashes of light and crackling sparks produced on making and breaking contact with the poles of this grand battery, are very undesirable phenomena in one particular. They are accompanied by a considerable waste of the metal of the pole. Each spark is really a considerable fragment of the metal absorbed into itself by the electrical agent, so to speak, and flown away with by it. Lightning itself is now known to be material substance thus seized upon and converted into electrical flame. When one of the poles of the battery is drawn two or three times along the sharp angle of an iron instrument, like a pair of pliers, the opposite end of the pliers being in contact with the other pole, the sharp angle is shaved away in the midst of a shower of sparks, just as if some irresistible and adamantine-toothed file had been carried along the same course. As the signals of the Telegraph will be constantly made by making and breaking contact with the poles of the battery, these sparks would prove very costly and troublesome, eating away the material of the contact-key, and what is of more importance, very soon deranging its integrity and perfection as a mechanical means of communication and transmission. The Electrician of the Company has very nearly eliminated this difficulty by a contrivance of considerable ingenuity. First he arranged a set of twenty brass springs, something of the form and appearance of the keys of a musical instrument, in opposite pairs, so that a round horizontal bar, turning pivot-ways on its own centre, and flattened at the top, could lift by an edge either of the sets of ten springs, right or left, as it was turned. This enabled the contact to be distributed through the entire length of the edge, and breadth of the brass springs, and the course of the current to be reversed, accordingly as the right or left edge (the bar being worked by a crank handle,) was raised to the right or left set of springs; the right set, it will be understood, being the representatives of one pole of the battery, and the left set of the other pole. By this arrangement four-fifths of the spark were destroyed, simply on account of the large surface of metal, through which the electrical current had to pass when contact was completed. Still there remained enough to constitute a very undesirable residue. This was disposed of finally, after sundry tentative attempts, by coiling a piece of fine platinum wire and placing it in a porcelain vessel of water, and then leaving this fine platinum coil in constant communication with the opposite poles. As much electricity as this little channel can accommodate is constantly running through it from pole to pole, making it very hot, but it is kept from getting red-hot by the water in which it is immersed. The water is sustained at a boiling temperature to the relief of the fine filament of heated metal. When contact

is made or broken by the key; this subsidiary contrivance being in operation, the main body of the current passes through the key, and the slight leaking still goes on through the platinum wire, but no spark appears. The contact is entirely lightless and quiet. The spark is absorbed in the maintenance of the leak. There is a slight increased consumption of zinc in the battery on account of this leak. The battery is always in subdued operation, instead of being in absolute rest between the successive contacts made for the transmission of the currents. This is seen upon going into the room where the battery stands. There is a continued but very gentle effervescence with the disengagement of bubbles of hydrogen. While the full contact is being made the effervescence rises into marked ebullition. When however all contact is broken, the effervescence subsides, and very soon ceases, and the several compartments of the cells present nothing but a clear, pellucid depth of clean tranquil liquid, which would have instantly earned for this mighty combination, had it been the Eastern instead of the Western oceanic gulf of the earth which it was designed to work across, the very appropriate name of the "Pacific Battery." It may be added that one of these perpetual maintenance batteries has now been constantly at work for months in a large electrotyping office in London, and has thoroughly established its reputation for unparalleled steadiness, convenience, and power. The battery is also unquestionably one of the most economical that has ever been set to work, considering the amount of service it is able to perform. It is calculated that the cost of maintaining the ten-celled battery in operation at the terminal stations on either side of the Atlantic, including all wear and tear, and consumption of material, will not exceed one shilling per hour.

Thus much of the primary source of electrical power, whence the telegraphing influence will issue for the Atlantic passage. The important addition has now, however, to be made, that it will not be the direct emanation from this Titanic battery, which will really cross the Atlantic. If it were so, it would strictly be the "voltaic current" which would cross the long ocean-stretch. But it will be remembered that the voltaic current has been determined to be far more sluggish of movement than some electrical agencies, with which it stands in sympathetic relation. Consequently, this primary voltaic current will only be used to stimulate, and call up the energies of one of those fleeter messengers. The voltaic stream is sent to a piece of complicated electrical apparatus, consisting of miles of silk covered wire, rolled into almost countless coils, which envelope a bar or core of soft iron. The iron bar itself is enclosed in a sheathing of tolerably thick sheet gutta percha, and there are deep flanges moulded on the sheath to divide the coiled wire into segments,

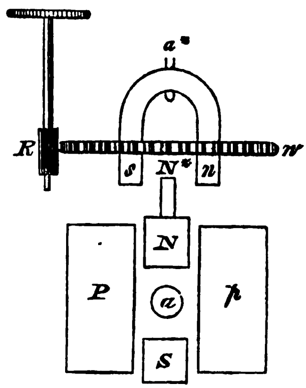
so that a more perfect separation and insulation may be maintained. First, several miles of sheathed wire of the comparatively fine No. 20 gauge is wound tightly round the core. That is a secondary passive, or *to be excited* coil. This coil is covered by a layer of gutta percha, and round this a mile and a half of sheathed wire of the comparatively thick No. 14 gauge is wound, arranged in 24 short lengths. That is a primary, inducing, or *generating* coil. The thick primary coil is placed in circuit between the poles of the voltaic battery, and receives the voltaic current when signals are to be made. Then this is what follows:—The soft iron bar in the centre of the coil becomes a very powerful temporary magnet, and the powerful magnet, in its turn, excites a current of electricity in the thin secondary coil, and that secondary induced current is caused to start off across the Atlantic through the conducting strand of the cable. It is indeed the *transmission current.* The voltaic current induces magnetism in the iron bar, and the magnetized bar induces an electric current in the inner coil without there being any direct communication established between its insulated wire, and either the magnet or the wire of the primary coil. The coils are thus properly *double-induction coils.* Electricity induces magnetism, and magnetism induces electricity, which then possesses the remarkable and valuable property of a facility and speed of motion far exceeding that of any producible simple voltaic current. So far as mere quantity is concerned, the electricity called forth in the secondary *transmission coil*, is less than that which is directly poured into the primary generating coil by the voltaic battery, but it is of far more intense power, and goes forth into the cable amply prepared for its work, and abundantly strong and brisk for the effort of leaping across the Atlantic in the tenth part of a second. It is peculiar to these powerful instruments to have the secondary or transmission coils bound immediately round the magnetic bar, inside of the generating coil. This arrangement is adopted because it enables the magnet to act with increased advantage upon the wire it has to make active through induction. If the transmission coil were outside the generating coil, the magnet would have to act upon the former through the latter. There are in the instruments prepared for telegraphic use, a pair of the double-induction coils placed side by side, because each of the temporarily-formed magnets inductively strengthens the force of its neighbour; if short bars are laid connective *across* the ends of the parallel bars, these also become magnets by induction, while the electrical currents are flowing, and in their turn re-act upon the larger bars, and make their magnetism and inducing power stronger. A short wire coil curled round one of the transverse bars, or bud-magnets, has a subordinate or affiliary current called up in it, which is

necessarily simultaneous in the time of its production with the ordinary transmission or secondary current, and therefore available in various ways for experimental research. In the preparation of these double induction coils, similar care to that already alluded to has been taken to have each separate agency accurately proportioned to its co-workers, and the labour it has to perform. If by accident the current which ought to be transmitted through the entire length of one of the coils, finds its way by a shorter route, the instrument immediately becomes heated to a very considerable degree, and thus furnishes, of its own accord, a warning indication of the derangement. Although the electrical influence generated in these coils is possessed of a very much higher penetrative power than the simple voltaic current, it is nevertheless found to be advantageous not to allow it to approach in intensity to the influence which is called forth by the apparatus known under the designation of the Rhumkorff coil.

The transmission current generated in these double-induction coils, on reaching the further side of the Atlantic, will of course have become somewhat faint and weak from the extent of the journey it has performed. It will not therefore be set, in this state, to print or to do hard work; but it will be thrown into a sort of sanatorium or nursery, known as the receiving instrument, where its flagging energies will be restored. The conducting strand of the cable will be here made continuous with a coil of wire, surrounding a bar of soft iron, which will become a temporary magnet, strong in proportion to the number of turns in the coil, whenever the current passes. This temporary magnet will have its precise polarity determined by the direction in which the electrical current passes along the wire. The pole which will be north when the current passes in one direction, will be south when the current runs the opposite way.

This temporary magnet, made whenever the transmission current arrives across the Atlantic, and courses through its investing coil, will then be the base of the receiving instrument. An apparatus of a somewhat similar nature to this has been in use for some time, under the name of a relay. But the receiving instruments to be employed in the Atlantic service possess one feature which gives them a very remarkable and important advantage over the old "relay" apparatus. In the old "relay" the magnet pulled down a bar of soft iron when it was made magnetic, and when the magnetism failed, the bar was drawn back by a tolerably strong spring, so attached as to act in the opposite direction. Thus the magnet always had the opposition of the spring to overcome every time it acted, and so a great expenditure of power was necessitated. In the new receiving instrument, Mr. Whitehouse has

dispensed with the spring, and adopted an arrangement which will be best understood by a reference to the accompanying rough diagram. The instrument is supposed to be seen by a vertical section made across it, as it lies along on its extended base. *P p* represent the two poles of the soft iron bar, which is temporarily magnetized by the transmission current. This temporary magnet is bent into a horseshoe form. Between its arms is placed a small permanent horseshoe magnet, turning right and left upon a central pivot;—*a* represents the position of the pivot, and *N* and *S* the situation of its north and south poles. Now north poles of magnets attract south poles, and south poles attract north. Consequently, when *P* is temporarily made a south pole, it attracts *N*, and *p* attracts *S*, and the permanent magnet is rotated upon its pivot, until the contact of *P* and *N*, and of *p* and *S*, takes place. But when *P* is made a north pole, it attracts *S*, and *p* attracts *N*, and the permanent magnet is rotated the opposite way. When the permanent magnet is rotated one way, the circuit of a small local battery is closed, and it is set to record signals; when the permanent magnet is rotated the opposite way, the circuit of the local battery is opened, and the recording work stops. The north pole of the permament magnet is extended to *N**, and is there embraced between the poles of *s n* of another small permanent magnet, which rotates upon a central pivot, *a** being carried by a tooth-wheel *w*, moved by a pinion, *R*. This part of the instrument accomplishes a fine magnetic adjustment, by regulating the facility with which the permanent magnet obeys the polar attraction of the temporary magnet. The more *s* is drawn round towards the pinion, the more it tends to drag *N* towards *P*, and so to reinforce the polar power of *P*. When *s* and *n* are placed in a position that is perpendicular to the plane of the sketch (that is to the paper), they cease to exert any influence over the rotatory motion of the magnet *N* and *S* upon its pivot, *a*. In working out this magnetic adjustment, Mr. Whitehouse availed himself of the suggestion afforded by a magnet regulator Mr. Bright had contrived for the Magnetic Company's needle-instruments some three or four years previously.



The advantage of this relay, then, is that the temporary magnet has no other work to do than to make the small permanent magnet traverse upon its almost frictionless pivot. On account of this pecu-

liarity of construction, it possesses the utmost sensibility. It may be put into vigorous action by a sixpence and a fragment of zinc placed on the moist tongue. When two or three of these instruments are scattered about in the room where the large double-induction coils are at work, they are commonly heard clicking backwards and forwards automatically, and doing a little business on their own account, although no current of any kind is thrown upon their coils. They are then merely traversing upon their pivots, obediently to the magnetic attraction of the great bars, having their magnetism successively reversed some two or three yards away, and curiously enough, are sympathetically recording, at such times, precisely the same signals and messages that the great magnets are sending off through the transmission coils.

But how will these sensitive receiving instruments lead to recording work being performed? The chain, as far as it has been linked together up to the present, stands thus. A powerful voltaic current goes through a generating coil near at hand. The generating coil makes a temporary magnet. The magnet produces a transmission current in a secondary coil. The current crosses the Atlantic in the cable, and makes a temporary magnet on the farther side of the ocean. The temporary magnet works a permanent magnet hung on a pivot, so that it can traverse. The next link in the chain is this; there is a local short circuit voltaic battery standing ready near the recording instrument, and this battery has its electrical flood-gates opened when the permanent magnet traverses one way, and shut when it traverses the other. When the flood-gates are opened, the current from the local battery flows out, and prints the message it is desired to record. The perpetual maintenance batteries, double induction coils, and springless sensitive receiving instruments, designed for the work of the ocean telegraph, have all been made expressly for the work, under the eye of the electrician of the Company, and indeed, are most of them inventions for which patent rights are held. The actual recording work of the telegraph will be performed by the ordinary instrument of Professor Morse, carefully adjusted in the workshop of the Company.

In this recording instrument, a ribbon of paper is unrolled from a hollow cylinder or drum by a train of clock-work, and as it is unrolled, a sharp style, magnetically directed, indents a series of dots or lines upon the paper. When the style is thrust down only for an instant as the paper is dragged along beneath, a *dot* is impressed. When it is kept down for a little more than an instant, a lengthened line or *dash* is left on the onward moving paper as a track. But how is the style thus magnetically controlled? It is held up by a strong spring.

Beneath it there is a soft iron bar, which becomes a magnet whenever a voltaic current is turned on from the local battery along a coil surrounding it. Whenever the soft iron bar becomes a magnet, it is stronger than the spring, and drags down the style to make its dot or dash, as the case may be. When it ceases to be a magnet, the spring comes into play and lifts the style up, so that the paper traverses on beneath, traceless and free. The style is held down an instant, or more than an instant, accordingly as an instantaneous, or as a prolonged current is sent from the transmission coil, and therefore from the local recording battery through the short circuit; for as it has been seen, the two will be in magnetic and electrical rapport, although severed by the Atlantic's breadth.

There will be only one conducting strand laid down in the Atlantic, but yet enough distinct signals can be transmitted by this one wire to accommodate all the letters of the alphabet and the several numerals. The *dot* and *dash* code of Professor Morse is adopted for this purpose. Different combinations of these two elementary signals are easily arranged, so as to express all the letters and numerals required. Thus, for instance, dot and dash, .— represents a; dash and three dots, —... b; dash, dot, dash, dot, —.—. c; dash and two dots, —.. d; one dot, . e. The word dot, spelt in the dot and dash character, would read —.. ——— — When a message is sent across the Atlantic, the crank-handle of the mighty battery will be worked backward and forward, making its contacts instantaneous or prolonged; when they are instantaneous, dots will be formed on the paper ribbon by the recording style at the other side of the Atlantic; when they are protracted, dashes will be traced there. Words will be spelt according to the way in which instantaneous and protracted contacts, and therefore dots and dashes are caused to succeed each other. The trace on the paper in America will correspond to the movement or the hand in Great Britain, or *vice versa*. The clerks who attend at the recording instrument become so expert in their curious hieroglyphics, that they do not need to look at the printed record to know what the message under reception is, the recording instrument has for them an intelligible articulate language. They understand *its speech.* They can close their eyes and listen to the strange clicking that is going on close to their ear, whilst the printing is in progress, and at once say what it all means. Mr. Bright has introduced a very ingenious piece of apparatus, based upon this observed facility, which will, in all probability, ultimately come into use on the Atlantic line. There are two bell-signals, one muffled, and the other clear, which are understood to stand as audible representatives of dots and dashes. The

clerk who receives a message, sits with his head bent down, a pencil in his hand, a paper resting before him, and a bell at his side. He writes down on the paper what the bell says at his ear. When the muffled sound occurs, he interprets it a dot, when the clear sound, a dash. The cypher of this "Phono-telegraphy" is translated by the rules of the ordinary dot and dash code.

It is quite possible to make an ordinary sensitive galvanometer subservient to the transmission of the dot and dash signals. A horizontal needle being placed so that its north pole is directed towards the magnetic north of the earth, may have two ivory stops arranged so as to limit its movements to slight deflections on either side. Then a wire in continuation of the transmitting conductor or cable issuing from from the signal battery, being wound about it in the form of a coil, the needle of the galvanometer will be deflected whenever a current is sent through the wire and coil. If the current which is passed be but an instantaneous one, the needle will strike the ivory stop for an inst[illegible] current be protracted for a sensible time, the needle will hug the ivory stop for a sensible time. The instantaneous touch of the needle and the stop may then be taken to signify "*dot*," and the prolonged touch to mean "*dash*," and words may be spelt out by the common dot and dash alphabet. To prove the surpassing sensitiveness of this simple arrangement, one of the horizontal galvanometers in common use as a testing instrument, was placed on a table, and the needle allowed to assume its position of magnetic polarity and rest. A battery was then formed of two little plates, silver and zinc, each having the size of the accompanying figure.  These were fixed in a transverse support, so that there was just space for a drop of liquid to hang suspended by its own adhesion between them. This battery was then charged by insinuating a drop of acidulated water between the plates, and the zinc plate was connected with the earth by a wire, while the silver plate was connected with one thousand continuous miles of the Atlantic cable, which transmitted its current through the galvanometer to the earth at the further end. When contact was made, and the current of this almost infinitesimal battery was transmitted through the thousand miles of cable to the galvanometer, clear and bold deflections of the needle were almost instantly made, and it was found that these deflections could be most readily caused to signal the dot and dash characters. The beat of a seconds pendulum was counted while the signalling was in progress, and it appeared that this very weak current required something under three seconds for its transmission through the thousand miles of cable. The deflection of